VOL. V, NO. 4 DECEMBER, 1930

THE QUARTERLY REVIEW of BIOLOGY

EVOLUTION OF FACIAL MUSCULATURE AND CUTANEOUS FIELD OF TRIGEMINUS

PART II

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VII. THE FACIAL TACTILE VIBRISSAE IN THE LOWER PRIMATES. EVOLUTION OF MIMETIC MUSCULATURE AND FACIAL EXPRESSION IN THE ASCENDING SCALE OF PRIMATES UP TO MAN. EMBRYOLOGICAL DEVELOPMENT OF THE HUMAN FACIAL MUSCULATURE. RACIAL DIFFERENCES IN FACIAL MUSCULATURE AND FACIAL EXPRESSION

THE *Prosimiae* (lemurs and *Tarsius*) have retained the primitive marsupio-placentalian ground plan of facial tactile vibrissae which can be moved by contraction of voluntary muscles of the facial group. In the lemurs (fig. 28) facial tactile sense, together with well developed sight and hearing, evidently plays a guiding rôle. Also for *Tarsius* (fig. 29) this facial tactile sense is a valuable addition to the highly evolved sight and hearing.

Within the *Simiae* in the most primitive forms, represented by the lower platyrrhine monkeys, such as the Hapalidae (fig. 30), and *Nyctipithecus* (*Aotus*) (fig. 31a and b) among the Cebidae, the tactile facial vibrissae are arranged in a way very similar to that in *Tarsius*. They have, however, undergone further reduction. As to the superficial facialis musculature the marmosets and *Aotus* show a primitive ground plan similar to that of *Tarsius*, if we disregard the specializations in the latter. But there are other striking simian features which the marmosets and *Nyctipithecus* share with the higher platyrrhines and lower catarrhines. The functioning of the superficial facialis muscles as mimetic musculature in the Hapalidae and the primitive Cebidae is still on a very primitive level. Indeed, these lowly primates have little facial expression.

As we ascend in the "simian scale" we notice that facial tactile vibrissae cease to be essential structures. They still persist, however, as vestigial sinus hairs, in the supraciliary region, not localized there, however, in a single patch, as in the lower platyrrhines, prosimians and the rest of the placentals and the marsupials, but secondarily scattered over the entire supraorbital margin; facial vibrissae are moreover found on the upper and lower lips.

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It is noteworthy that those facial muscles (*M. depressor supercilii*, *M. maxillo-naso-labialis* (in part), *M. mentalis*), which in the primitive primates move the well developed facial vibrissae, presumably having evolved in close correlation with this tactile apparatus, persist in the higher primates, despite the deterioration of the tactile vibrissae. They are, however, modified structurally and have altered function.

The deterioration in the higher primates of an originally important tactile mechanism, is obviously in close correlation with the further elaboration of the visual apparatus, with the evolution of the anterior extremity, especially the hand, and, in the case of the higher platyrrhines, with the acquisition of a prehensile, sensitive tail (see also Wood Jones and Porteus, 1918; Tilney, 1928, and others). By combined use of their eyes, hands and prehensile, sensitive tail these primates possess a much fuller orientation in their surroundings. This great improvement in the organization must have been an important factor in the further evolution of the neopallium, which brought higher intelligence,—a development which is also reflected in a more elaborate facial expression of these primates. Elaboration of facial expression goes hand in hand with a further differentiation of the mimetic musculature (fig. 31c and d contrasted with fig. 31a and b) and the involved central nervous mechanism.

In the lower catarrhines, as the macaque (fig. 32) for example, facial expression is still largely stereotypical. The gibbons (fig. 33) are intermediate between the lower catarrhines and the great anthropoid apes. In the great anthropoid apes the elaboration of the central nervous mechanism, including the differentiation of the facial area of the motor cortex, has reached a higher degree than in the gibbon and the lower catarrhines (compare chapter III). Side by side with this goes a further differentiation of the mimetic musculature (figs. 34, 35 and 36). This gave the basis for a more complex though still rather crude grimace-like facial expression. Nevertheless a large range of individual features of expression is noticed in these highly intelligent animals (compare Yerkes' *Almost Human*, 1925).

In *man* facial expression has finally reached marvelous perfection. This phenomenon may be attributed to further differentiation of the mimetic musculature (compare figs. 39–46), in close correlation with higher evolution of the central nervous mechanism, i.e. further development of the facial area in the motor cortex and through elaboration of the association centers.

Taking into consideration the fact that spontaneous facial expressions with their manifold delicate shadings result from varied emotional reactions, we may conclude that the elaboration of facial expression during the phylogeny of man closely followed the evolution of emotional life, which in turn depended on the elaboration of the association centers. We may further assume that evolving man consciously used and developed certain facial expressions in order to make himself understood by his fellow creatures in a fuller and more definite way. We still notice occasionally in modern man imperfect functioning of one or another of the mimetic muscle groups. Thus additional muscles may contract when the contraction of a limited group is intended by the individual. There are occasional individuals who cannot contract the superciliary and glabellar muscles without at the same time tightly closing the eyes with the *M. orbicularis oculi*. This phenomenon is presumably a persistance of a phylogenetically older, less differentiated pattern. Through special

effort and with continued practice, however, such persons may succeed in eliminating the associated contraction of the *M. orbicularis oculi*, thereby perfecting the independent play of the *Depressor supercilii-corrugator-procerus nasi* muscle group, as is ordinarily done in frowning. We may assume that through such a process of gradual functional perfection finely graded facial expression has evolved from a lower stage, where crude, grimace-like group action of mimetic muscles prevailed as in the facial expression of the anthropoid apes and lower primates. There can be no doubt, moreover, that the acquisition and gradual perfection of articulated language has had a further decisive influence in the evolution of the mimetic musculature and facial expression.

It should be emphasized that the individual mimetic muscles lack a well defined muscle fascia, in contrast to the skeletal muscles, in which the bundles are solidly bound together into compact structures by such fasciae. Hence, in the case of the mimetic musculature, smaller muscle portions, even single muscle bundles, may contract independently of the rest of the muscle,—this in manifold combinations with synergetic muscle portions within functional muscle groups. The richly branched facial nerve affords the necessary motor innervation to these various muscle portions.

Moreover, it is significant that the coherent superficial body fascia, although it covers as a thin sheath the pars colli of the platysma, does not extend into the face. A fascial cover, like a veil spread over the delicate, thinly bundled mimetic musculature, would of course make elaborate facial expression impossible. The mimetic muscles lie directly subjacent to the freely movable skin. There the inserting muscle bundles are anchored in the subcutaneous tissue, or firmly attached to the cutis itself. The latter method of attachment holds in the superciliary region, in the naso-labial fold, over the chin, and in the lips. Under the influence of the contracting mimetic muscles the elastic skin is laid into folds, which as a rule are at a right angle to the direction of the muscle bundles. Since, in compound facial expression, series of muscle portions with different bundle directions are simultaneously set into action, the wrinkling of the skin becomes complex. In those areas where the muscle bundles insert directly into the cutis, muscle contraction brings forth, not wrinkles, but grooves or dimples. Individual muscle variations, differences in thickness of the cutis and subcutaneous tissue and differences in the elasticity of the skin naturally have modifying influences, thus adding to the individuality of facial expression.

Detailed studies of the morphology of the human mimetic musculature with careful consideration of the innumerable individual variations afford evidence for the view that evolution of the central nervous mechanism preceded the evolution of this muscle apparatus. The superficial muscle complex in the temporal region, the *M. occipitalis* and the entire ear musculature in man are found in a stage of progressing degeneration. The functional deterioration has gone further than the structural degeneration. While many, perhaps most persons still possess the ability to control the *M. occipitalis*, those are fewer who are still capable of contracting the extrinsic ear musculature in attempts to move the ears. It is usually the *M. auricularis posterior* which can be contracted if set into action jointly with the *M. occipitalis*. These two muscles form an old phylogenetic and functional unit. Still rarer are the persons who are able to contract the *M. auricularis posterior* alone. Such action is usually accompanied by an increased

innervation of the *M. occipitalis*, which is appreciated by tightening of the galea aponeurotica. Rare, indeed, are the individuals who can set into action the *M. auricularis anterior et superior*. In the intrinsic ear musculature, the functional deterioration evidently has progressed still further. It is very doubtful whether any of these little muscles can be voluntarily moved at all, although they persist as well defined muscle masses with apparently intact nerve supply.

In contrast to the evident deterioration of the above named groups of the superficial facial musculature, we find the musculature of the face proper, the "mimetic muscles" in the strict sense, in a state of progressive development. This musculature has by no means reached an end stage of evolution. We can not fail to recognize in certain of these groups a trend towards fuller differentiation into distinct individual muscles. Thus evolution seems to be still intensely at work in the muscle field of the glabellar and supraorbital region and in the musculature about the mouth. We encounter in these areas all possible transitions from very primitive conditions with persisting old phylogenetic muscle connections, to progressive states, where the individual muscles are more clearly differentiated. It is in these areas with the most highly differentiated muscle groups that the most vivid facial expression is noticed. In some individuals the musculature around the eyes and in the glabellar region is more responsive, while in others the musculature about the mouth becomes outstanding in facial expression. Often both groups are equally responsive. It is interesting to see that in man the functional perfection of the mimetic musculature has progressed much further than the structural differentiation of this muscle field.

In connection with the study of the morphology of the mimetic musculature, investigations on representatives of races other than the white are of great interest. The very active period of *racial anatomical research* during the first three decades of the twentieth century considerably furthered our knowledge of the mimetic musculature in various races of the human stock, especially of "Negroes," Papuans and Melanesians, Australians, Malays, Chinese, Japanese, Indians, in contrast with the Whites.

The author had the opportunity to investigate a large series of American Negroes (fetuses, new-born, children and adults of both sexes), and to compare them with the White, with an adult Chinese and an adult Hawaiian (figs. 39–46). Through these studies he could support and supplement former authors, among them the pioneer Chudzinski, who was the first to keenly appreciate racial differences in the mimetic musculature and in the rest of the muscle system. It appears astonishing that a series of authors, some notable authorities, are still sceptical as to the occurrence of racial anatomical differences in the soft parts, including the muscle system. Yet more and more convincing data are brought together proving the existence of such racial differences. According to the author's experience the racial characteristics are more conspicuous in the mimetic musculature than in the rest of the muscle system, where racial differences are likewise recognizable. It is to be noted that these differences appear early in fetal life (compare fig. 40).

A vast amount of valuable data on the racial anatomy of the mimetic musculature has been obtained through the researches of many authors (see bibliography).

Although *attempts to analyze and explain facial expression in man* are very old the extensive literature on the "Science of Physiognomy," especially the older, is full

of worthless statements and fantastic speculation. However, a series of publications on facial expression initiated by the classical works of Bell and Darwin is on a sound morphological basis. Yet hardly more than a beginning has been made in broadly correlating facial expression with neuro-physiology. To quote just a few historically important or otherwise valuable and fundamental works in this field I refer to Lebrun, 1667; Camper, 1774, 1791; Lavater, 1775/78; Bell, 1806; Duchenne, 1861; Gratiolet, '65, '72; Piderit, '67; Darwin, '72; Wundt, '77; Birch-Hirschfeld, '80; Montegazza, '90; Bugnion, '95; Rudolph, 1903; Virchow, '08; Krukenberg, '22; Lightoller, '25, '28.

While in the evolution of facial musculature and facial expression during the phylogeny of man, the elaboration of the central nervous mechanism evidently precedes the structural differentiation of the mimetic muscles, this is not the case in the *individual development*. The mimetic musculature receives its structural differentiation very early in fetal life. The critical period of development and differentiation is between the second and third month (fig. 39). In the three months' fetus (fig. 39d–f) this muscle field is already regionally differentiated, and the principal branches of the facial nerve are formed (Huber). Up to the fifth month (figs. 40, 41a), however, the mimetic muscles are found to be rather delicate and of gelatinous, half transparent consistency, which renders their dissection and study difficult. From this period on (fig. 41b and c) the muscle bundles receive their final structural differentiation and characteristic reddish coloring, and the proportions of the individual muscles become more and more those of the new-born, illustrated in figures 42 and 43a.

Postnatal changes are slight. The mimetic muscles grow in proportion to the whole head, while the growth of the masticatory musculature on the other hand goes side by side with the growth of the mandible, which is largely determined by the dentition. It is noteworthy that the two muscle groups, the mimetic and the masticatory musculature, which are situated so closely together, develop at a very different rate.

In contrast to the completed structural differentiation of the mimetic musculature and corresponding peripheral facial branches at birth, there is practically no *facial expression* in the new-born. Expression evolves very gradually in connection with the completion of the development of the sensory mechanisms and with the elaboration of association centers. As the young infant's conscious and intelligent reactions to the surrounding world grow, facial expression becomes more manifold and more definite. There is remarkable progress during the first year, and the second and third years bring further elaboration (compare also Buchner, Preyer, Bugnon, Krukenberg *et alii*). Facial expression resulting from emotional reactions (upon adequate external stimuli or upon associations of ideas, which revoke memories of past experience), remains unmasked through childhood. It is thus possible to read in the child's face the true meaning of the manifold expressions with all their rich modulations.

Facial expression is evidently a highly complex reflex action, in which the highest cortical centers are involved. Certain impulses arising in association centers, reach the facial area of the motor cortex and, when sufficiently strong, they seemingly release, against our will, motor impulses to the mimetic muscles. While a person is awake, the mimetic muscles, like the rest of the voluntary muscle system, are kept in a state of tonus, ready to contract at any time. Yet the intensity of tonus varies

according to the state of attention of mind. It varies from person to person. Motor impulses which reach the mimetic muscles may simply increase this tonus, or they may set the various functional groups into mimetic musculature goes the expression in the eyes, a mechanism which would deserve special discussion. As regards facial expression it should be emphasized that spontaneous contraction of voluntary

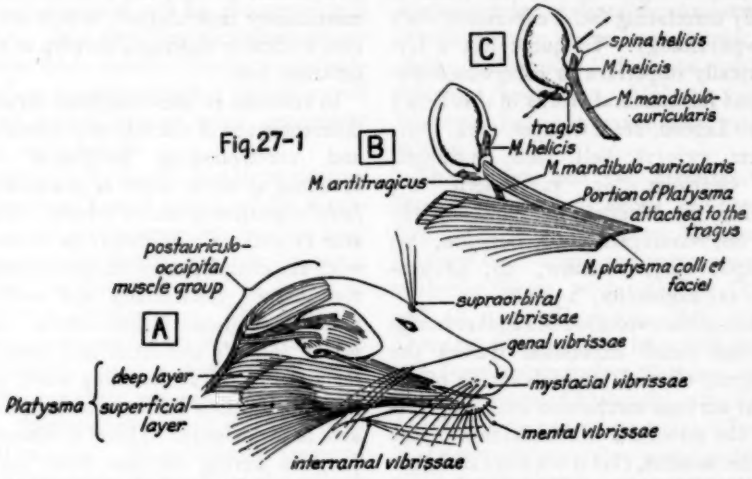

FIG. 27. SCHEME OF THE PRIMATE GROUND PLAN OF SUPERFICIAL FACIAL MUSCULATURE AND FACIAL TACTILE VIBRISSAE, FOR THE UNDERSTANDING OF THE FOLLOWING SERIES OF UNLABELLED FIGURES REPRESENTING FUNDAMENTAL TYPES OF THE "ASCENDING SCALE OF PRIMATES" (compiled from the actual findings in the lemurs, Tarsius and lower platyrrhine monkeys)

Fig. 27–1. The Platysma and its Derivatives

A. The Platysma is seen in a primitive arrangement, arising with a deep layer from the nuchal region as in the original marsupio-placental ground plan of fig. 6, part I, while the "primitive sphincter colli," the matrix of the entire superficial facial musculature (compare fig. 6), has dropped from the primate ground plan. The postauriculo-occipital muscle group (*M. occipitalis*, part of the extrinsic and intrinsic ear muscles) with the nuchal portion of the platysma remained in primitive connection. The deep and the superficial layers of the platysma unite to build the uniform plate of the *M. platysma colli et facies* (compare also fig. *b*). The most caudal bundles of this muscle deviate towards the shoulder region. Note the full set of well developed *facial tactile vibrissae* in an arrangement characteristic of the original marsupio-placental ground plan of fig. 23, part I.

B. The *M. platysma colli et facies* is joined by a muscle band (*M. auriculo-labialis inferior*, Ruge), which posteriorly attaches itself to the tragus of the ear. On the ear cartilage note the *M. antitragicus* and *M. helicis*, muscles of the postauricular group, which have migrated from the posterior to the anterior surface of the ear, while the *M. mandibulo-auricularis* has still further intruded into the preauricular muscle territory by migration along the cartilaginous ear tube, towards the mandible, where it has gained attachment.

C. Anterior and posterior borders of the ear cartilage are here shown pulled a little apart in order to demonstrate the primitive connection of the *M. helicis* with the *M. mandibulo-auricularis*. The latter is represented as cut off from the mandible below.

Besides the muscles shown in the figures *a—c* the platysma gave rise in the higher primates to the *M. quadratus labii inferioris* and to the *M. rectus labii inferioris*. The rest of the superficial facialis muscles, including some of the extrinsic and intrinsic preauricular ear muscles, and the large bulk of the muscles of the face are derived from the *Sphincter colli profundus*.

contraction. Spontaneity, intensity and extent of these contractions are graded by the intensity of psychic impulses. Parallel with facial expression through the muscles upon emotional stimuli is a motor reaction largely characteristic of the facial field.

With increasing experience and under

the influence of education, the maturing individual learns to control spontaneous facial expression, and thus succeeds, to varied degree, in concealing emotions. We may assume that through this educational process emotional impulses, which in the child would invariably cause spontaneous response of the facial field, are counteracted or modified by a complex association mechanism before they reach the facial area of the motor cortex. As a result of this, reading the face of adults becomes difficult.

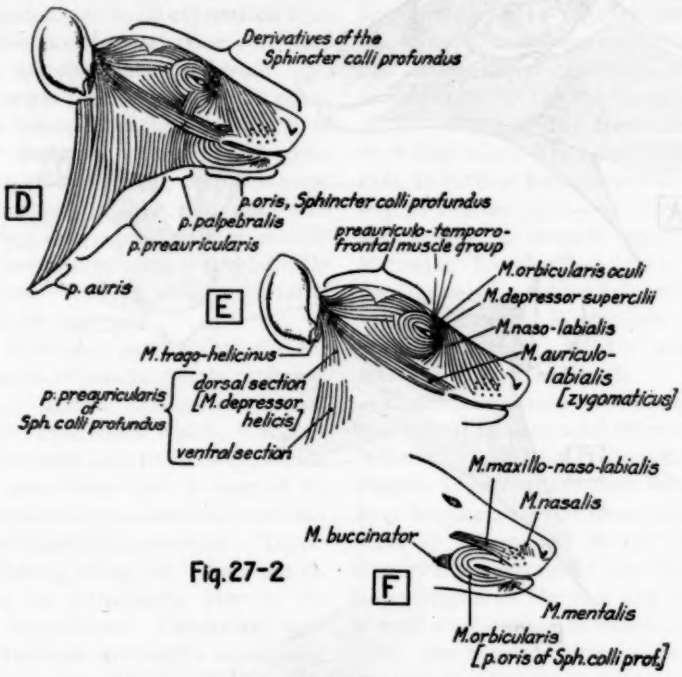

Fig. 27-2

Fig. 27–2. The Sphincter Colli Profundus and its Derivatives

D. The primitive arrangement of the *Sphincter colli profundus* represented by a continuous transverse layer, which extends from the ear to the mouth cleft, as in the original marsupio-placental ground plan of fig. 6, part I. While the most caudal section of the *Sphincter colli profundus*, the pars auris, inserts into the ear cartilage close to the incisura intertragica, the pars preauricularis of the *Sphincter colli profundus* has gained attachment to the helix of the ear. From here muscle portions have expanded over the upper part of the face, giving rise to a series of more or less distinct individual muscles. The derivatives of the *pars preauricularis sph. colli profundi* include the *M. trago-helicinus*, the preauriculo-temporo-frontal muscle complex, the *M. orbicularis oculi*, *M. depressor supercilii*, *M. naso-labialis*, and *M. auriculo-labialis* (*zygomaticus*). These muscles are once more represented in fig. *e*, where the dorsal section of the *pars preauricularis* (*M. depressor helicis*) *sph. colli profundi* is shown disconnected from the ventral section, which has remained part of the continuous layer of the *Sphincter colli profundus*.

The pars palpebralis of the *Sphincter colli profundus* (fig. *d*) inserts above into the lower eyelid, thus forming a *M. depressor palpebrae inferioris*. Anteriorly the p. palpebralis is continuous with the p. oris.

The pars oris, the most anterior part of the *Sphincter colli profundus* (fig. *d*) has given rise to the musculature of the snout, lips and cheek wall, as shown in fig. *f*, where the overlying *M. naso-labialis* has been removed. The derivatives of the pars oris are: *M. orbicularis oris*, *M. buccinator*, *M. maxillo-naso-labialis*, *M. nasalis* and *M. mentalis*. Additional individual muscles have arisen from this group in the higher primates.

It is true that we can, at any time, set

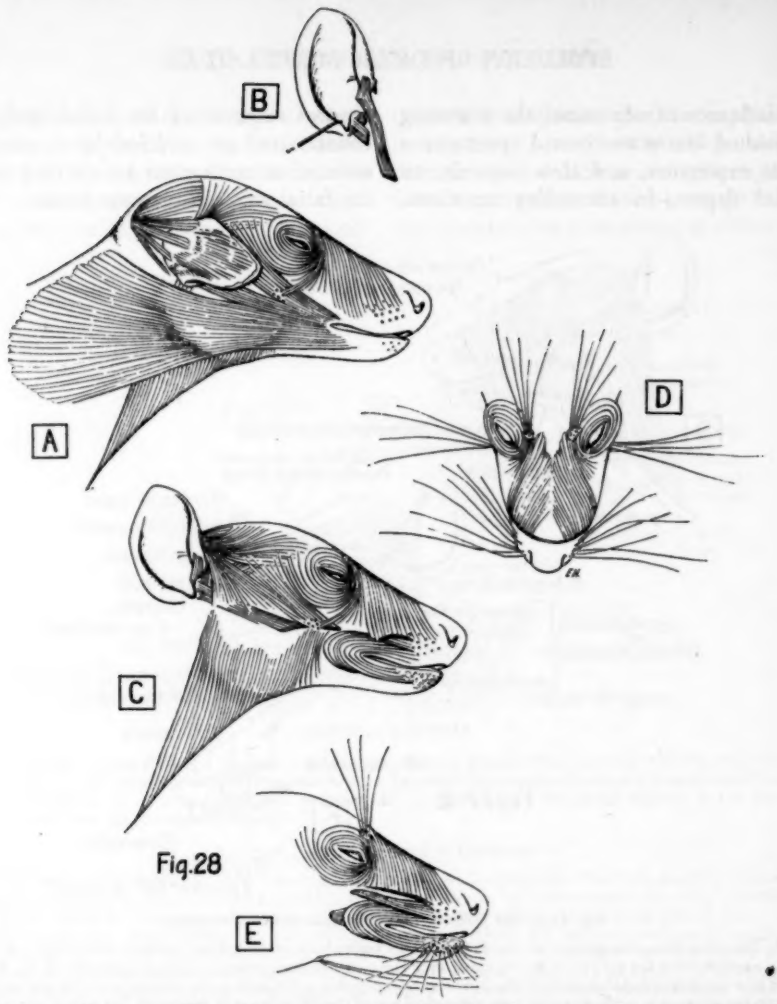

FIG. 28. LEMUR VARIEGATUS (JOHNS HOPKINS ANATOMICAL COLLECTION), WITH THE SUPERFICIAL FACIAL MUSCULATURE BUILT ON A PLAN COMMON TO THE LEMUROID STOCK

Fig. 28*a* shows the Platysma arising in a primitive way from the nuchal region and in close relation to the postauriculo-occipital muscle group, which is however no longer directly continuous with its matrix. Figure *b* shows the *M. helicis* and *M. mandibulo-auricularis*, muscles of the postauricular group, which have intruded into the preauricular muscle territory.

Fig. 28*c*. After removal of the Platysma the *Sphincter colli profundus* is seen, persisting as a continuous layer, with its most anterior portion (*p. oris*) encircling the mouth cleft. The dorsal section of the pars preauricularis (*M. depressor helicis*) has become separated from the *Sphincter colli profundus* layer, but has retained primitive connections with the musculature which has evolved from it, i.e. with the *M. trago-helicinus* and the preauriculo-temporo-frontal muscle complex, with the *M. auriculo-labialis* (*M. auriculo-labialis sup.* Ruge), and through the latter with the *M. orbicularis oculi* and *M. naso-labialis*. Noteworthy, and peculiar to the Lemuroidea and *Tarsius*, which share a common prosimian ground plan, is the broad connection of the *M. auriculo-labialis* with the platysma (compare fig. *a*). This is a secondary fusion (Huber) which simulates a primary connection (compare the older concept of derivation of the superficial facial musculature by Ruge, 1885, '87).

Fig. 28*d* gives an additional view of some of the derivatives of the *pars preauricularis sph. colli profundi*. At the same time it shows the arrangement of the facial tactile vibrissae. The complete original set of facial tactile vibrissae is present in *Lemur*, and these vibrissae are very well developed (compare further fig. *e*).

Fig. 28*e* shows the simple plan of the muscles of the lips and cheek wall, representing the derivatives of the *pars oris sph. colli profundi*.

As a whole the superficial facial musculature of the Lemur is on a primitive level, as characterized by the persistence of the nuchal portion of the platysma and the *Sphincter colli profundus* layer, by the lack of differentiation of the musculature of the upper part of the face and the simple plan of the orbicularis oris—buccinator group.

the various groups of the mimetic musculature into action just as we exert voluntary control over the rest of the voluntary muscle system. We are able to produce, at will, facial expression. But when we try to imitate complex facial expressions with all the fine modulations, these voluntary attempts lack spontaneity and truth. No other example could illustrate this generalization better than the vain efforts of poor or mediocre actors. Truly great actors, capable of strong, deep emotions, live so intensely in their rôles that with their power of imagination they concentrate on given situations as if they actually faced them. Through this their facial expression becomes true.

Facial expression may within the life time of an individual be greatly perfected. Continued mental concentration and deeply felt experiences which, whenever they are brought back to memory, set the mimetic musculature into a state of increased tonus or into contraction, naturally help to develop facial expression. Thinking and feeling along noble lines are reflected in the harmonious play of the mimetic musculature. Disturbing associated movements are hereby eliminated, and facial expression may thus attain admirable beauty.

With advancing age the elastic elements of the cutis and subcutaneous tissue lose elasticity, and the folds of the skin, which in younger individuals appear to be temporary, enduring only as long as the contraction of the mimetic musculature lasts, now become permanent. Thus lasting traits are gradually engraved into the human face. Since permanent wrinkles are best marked in those areas of the face which during life have been most frequently subjected to contraction, under varied influences, such as joy, grief, anger, etc., these wrinkles may reveal much about the past of the individual.

To these permanent wrinkles of adult life, are added also the so-called senile wrinkles due to wasting away of the subcutaneous tissue and shrinkage of the skin.

Very fascinating is the comparison of *facial expression in different human races*. The author has had opportunity to observe and analyse facial expression in different human types: in the more southern cities of the eastern United States of America with their mixed White and Negro population, in various Indian reservations, on a trip to Eskimo regions in North Alaska and during a summer spent on the Hawaiian Islands with their complex population of a native Polynesian stock, various types of Mongolians (Chinese, Japanese, Koreans), Whites, and Malays from the Philippine Islands.

These observations have convinced the author that distinct racial differences exist. Whoever has carefully observed faces of Negroes in comparison with Whites must have become aware of these racial differences in expression. In the responsive faces of *Whites* we notice, especially in the upper region of the face and about the mouth, a great range of varied expressions with many modulations. The mouth, even when closed, may serve as an admirable index of character or mental state through a slightly increased tonus of its musculature. A slight muscle contraction induced through complex associations of ideas may produce a fine gentle smile. As the underlying thought passes by, the expression around the mouth previous to the smile is gradually restored; but if stronger stimuli are added to the first, these will effect a more marked smile, because additional muscle portions now begin to contract and the ones already contracted are intensified in their action. The whole *M. quadratus labii superioris*, the *M. zygomaticus* and *M. risorius* may now be seen in action. As a result of this syner-

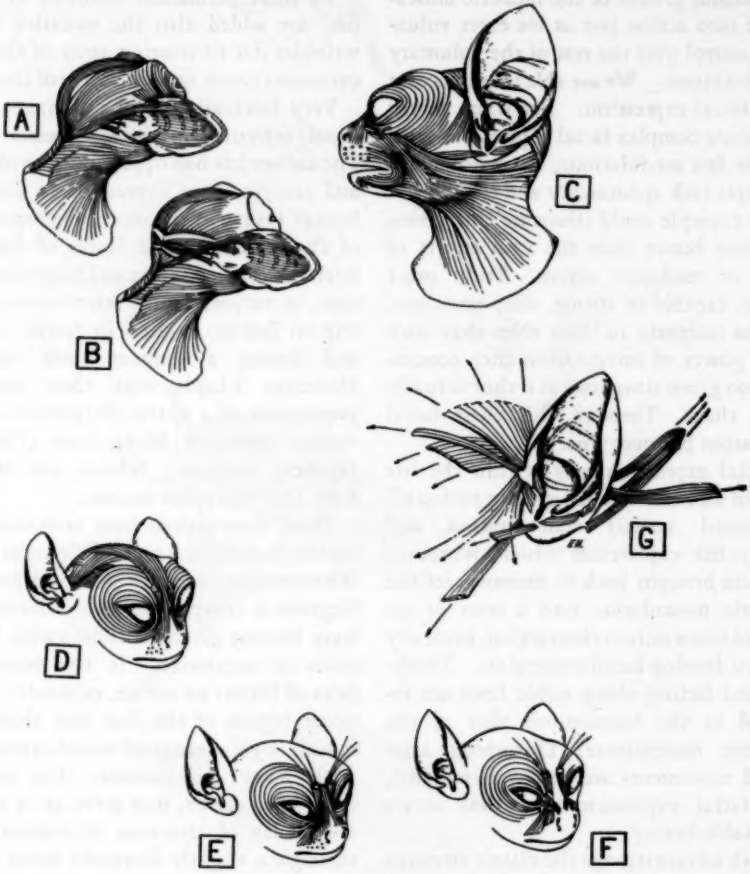

Fig.29

FIG. 29. TARSIUS SPECTRUM (A, B, D, E, F) AND T. SALTATOR (C, G), THE LATTER SOMEWHAT ENLARGED COMPARED WITH T. SPECTRUM (BOTH OF THE JOHNS HOPKINS ANATOMICAL COLLECTION)

The superficial facial musculature, practically identical in the two species is specialized on a primitive, distinctly prosimian plan (Huber).

Figs. 29*a* and *b* show the platysma in an almost schematically primitive arrangement, arising with the deep bundle layer from the nuchal region (ligamentum nuchae, processi spinosi of the lower cervical and upper thoracic vertebrae). Fusing with the superficial bundle layer it forms the *M. platysma colli et faciei*, which is seen in its full extension in fig. *c*. In the nuchal region the postauriculo-occipital muscle complex remained in primitive connection with the origin portion of the platysma (figs. *a* and *c*). The post-auriculo-occipital muscle complex is differentiated into a series of individual muscles, some of which have shifted their origins cranialward to the occiput (fig. *b*), as in *Lemur* (compare fig. 28*a*). The *Mm. obliqui et transversi*, which are derived from the extrinsic postauricular muscles, are extremely well developed. They cover practically the whole convex surface of the ear cartilage (figs. *a* and *b*), here bridging the grooves, which correspond to the four transverse ridges of the concave surface of the ear cartilage (compare figs. *c* and *g*).

The guiding senses of *Tarsius* are sight and hearing, with the auxiliary muscle apparatuses accordingly evolved and highly specialized along distinct lines peculiar to this genus. The powerful *M. orbicularis oculi* (figs. *c*, *d*, *e*, *f*), which protects the unusually big eyeballs, is noteworthy. The *M. orbicularis oculi* shows specializations (fig. *f*) nowhere else encountered in the order of the primates. Characteristic also is the conspicuous *M. depres-*

getic contraction of muscles the naso-labial fold, where the most powerful of these muscles insert, is deepened, the mouth is forced open and the smile turns into a happy, hearty laugh.

For these fine modulations of expression in the face of the White, a readily responsive neuro-mechanism, rather well differentiated, not too massive mimetic muscles (fig. 43) and a not excessively thick, elastic skin constitute the necessary basis. Naturally variations of the involved individual muscles, of the skin and subcutaneous tissue, and additional contraction of further muscle portions, e.g. in the region about the lateral angle of the eyes, over the back and lateral surface of the nose, greatly add to the individuality of expression in different persons.

Could we expect to find equally fine modulations of expression in the face of the *Negro*? The less differentiated, coarsely bundled mimetic musculature typical of the Negro referred to above (fig. 44a) and the greater thickness of the skin make this improbable. In fact there is a marked difference in facial expression compared with the White. But this is by no means due alone to the structural difference of the involved mimetic musculature and to the increased thickness of the skin, but probably more to the difference in functioning of the neuro-mechanism. Apparently less finely graded nerve impulses reach the respective mimetic muscle groups, thus setting them into sudden, strong contraction which rather suggests more primitive muscle actions. The expression is characteristic. Through the strong "labial tractors," especially through the undifferentiated Zygomaticus muscle-mass, the bulky lips are vigorously pulled upward and outward, so that the set of large-sized white teeth show up in contrast to the dark colored face. Instead of a graded laughing typical of the white we notice the characteristic grinning of the Negro. And through often simultaneously uttered sounds which differ in color of voice from those of the White, the Negro's grinning becomes even more characteristic.

The *Polynesians*, a highly intelligent race, dark skinned, like the Negroes, yet somatically and in regard to their psychology profoundly different,—show a distinctly different facial expression, similar to that of the White. I shall never forget the intelligent, pleasing and charming features of the kindly Hawaiian faces.

Very different again is the facial expression in representatives of the *Mongolian stock*. The schematic facial expression of the *Chinese* and *Japanese* is striking. For White people there is, at first, little individuality noticeable in those Mongolian faces. The expression seems rather indif-

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sor palpebrae inferioris (fig. *c*), which represents a powerful synergist to the *M. levator palpebrae superioris* of the oculo-motor group. With these two muscles as antagonists to the *M. orbicularis oculi Tarsius* may keep the eyes wide open.

The outer ear with the auxiliary muscle apparatus is highly perfected. Not less than ten distinct extrinsic ear muscles insert from different directions into the huge, spoon-shaped ear cartilage (fig. *g*). Well defined intrinsic ear muscles are supplied to adjust the entrance of the ear tube to incoming sound waves, and there are additional peculiar modifications of the ear cartilage. Thus the anthelix (*plica principalis*) is developed into a large shield (fig. *c*). There are, moreover, four transverse ridges on the concave surface which may be rendered more prominent through contraction of the above mentioned *Mm. obliqui et transversi*. And there is a little basket-shaped structure lodged on the lateral border of the scapha. All these are structures by which sound waves from practically every direction may be collected, and reflected into the ear tube. In the elaboration of the auxiliary apparatus to the visual and auditory mechanisms,—marvelous adaptations to exclusively nocturnal life, —*Tarsius* far excels the lemurs.

The facial tactile vibrissae, with the exception of the interramal group, are still distinct in *Tarsius* though not as conspicuous as in *Lemur*. Among the muscles which control these vibrissae the *M. depressor supercilii* is even more highly evolved than that of either lemurs or any representative of the simian stem. Through secondary fusion with a modified deep portion of the *M. naso-labialis* (figs. *e* and *f*) it has gained a broad bony attachment below on the maxilla (fig. *f*), an acquisition which renders this little muscle more efficient.

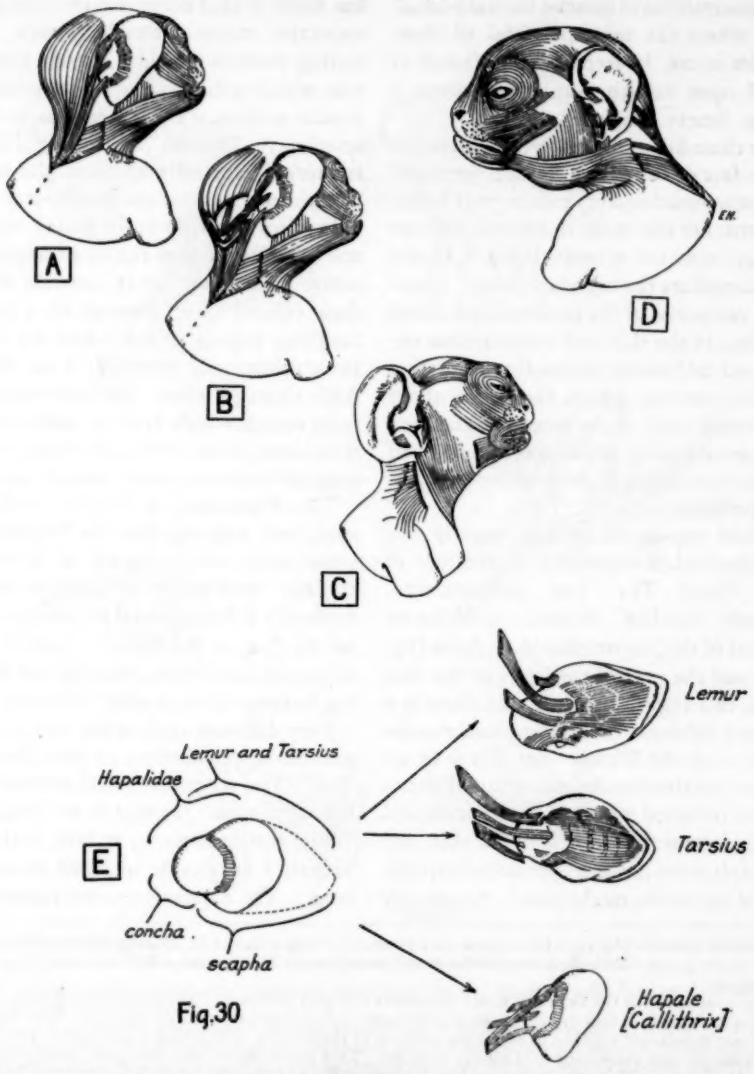

FIG. 30. HAPALE (CALLITHRIX) JACCHUS (FIGS. A–C) AND LEONTOCEBUS (OEDIPOMIDAS) GEOFFROYI (FIG. D) AS REPRESENTATIVES OF THE HAPALIDAE (MARMOSETS), THE MOST PRIMITIVE PLATYRRHINE MONKEYS (JOHNS HOPKINS ANATOMICAL COLLECTION)

The plan of the superficial facial musculature, practically identical in the two genera (compare also Ruge, 1887, and Schreiber, 1928), resembles that of *Tarsius*, if we disregard the specializations in the latter. Thus the platysma shows the same primitive extension, and the postauriculo-occipital muscle complex has likewise remained in primitive connection with the deep bundle layer of the platysma (figs. *a* and *b*). It is less differentiated and less specialized than in *Tarsius;* deep portions, however, (fig. *b*) have already shifted to the occiput, as in *Tarsius*.

ferent and the whole mimetic musculature appears to be in a stage of relaxation. Upon more careful analysis of single individuals one becomes aware, however, that Chinese and Japanese are capable of a far greater range of facial expression than we are accustomed to assume. These elements of expression represent, in part, characteristic features of their own. As to the expression of emotions we recognize that happy outbursts are expressed by these Mongolians through controlled smiling rather than real laughing. Through conservative, rather rigid education facial expression in the Chinese and Japanese is apparently suppressed. This view is supported by the fact that Chinese and Japanese who have lived long enough in countries with a prevailing white population in Western civilization show more spontaneity in their facial expression. They often become aware of this fact themselves, as I gathered in a series of cases.

Like the Chinese and Japanese the self-possessed, stolid *American Indian* shows little spontaneous facial expression, but through his mimetic musculature goes a strong tonus, which gradually brings out the sharply cut, keen traces so characteristic of many Indian faces. The *Eskimo*, on the other hand, gives a much more vivid response. Indeed through their spontaneous facial expressions, the Eskimoes show that they are a happy folk, despite their continuous hard struggle against the unfavorable elements of the far North.

From the preceding discussion it becomes evident that the analysis of facial expression of man involves most intricate problems. The solution of these problems requires closely correlated studies on the evolution of the mimetic muscles in the ascending scale of the Primates with emphasis on the large range of individual and racial variations in man, and on the gradual evolution of the complex neuromechanism. Of highest importance, and most difficult, is the analysis of the psychic component during the development from the new-born to the adult within the various human races. It should moreover be kept in mind that language may possibly have a modifying influence. Analysis, with the slow motion picture, of the muscle activity involved in uttering the various sounds during speech, shows the

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The *Sphincter colli profundus* (figs. *c* and *d*) has retained its primitive extension, and the *M. depressor helicis* in front of the ear remains part of the *Sphincter colli profundus* layer (compare also Schreiber, '28), while in the Lemuroidea and *Tarsius* on the other hand this muscle has been freed from its matrix. This very primitive condition in the marmosets is noteworthy. It proves that the preauricular musculature, the orbito-temporo-frontal muscle complex, *M. orbicularis oculi*, *M. depressor supercilii*, *M. naso-labialis* and *M. auriculo-labialis* (*zygomaticus*), together with the musculature of the lips and cheek wall, are indeed derivatives of the *Sphincter colli profundus* (Huber, compare chapter I) and not of the platysma (Ruge, 1885, '87).

In contrast to the Lemuroidea and *Tarsius*, there is in the marmosets no secondary fusion of the platysma with the muscle portion corresponding to the *M. auriculo-labialis* (*superior*) of the Prosimiae. While this latter muscle in the marmosets has retained its broad primitive connection with the *M. orbicularis oculi* (figs. *c* and *d*), it is reduced in its preauricular section, thus forming a *M. zygomatico-orbitalis*, which the marmosets share with the rest of the Simiae. The distal portion of the ear cartilage is considerably reduced in comparison with that of *Lemur* and *Tarsius*.

Fig. *e* shows the ear cartilage (viewed from the convex surface) with the extrinsic and intrinsic ear muscles in *Hapale* (*Callithrix*) contrasted with *Lemur* and *Tarsius*. The comparison shows strikingly how much indeed in *Hapale* the scapha portion of the ear cartilage has become reduced. The *Mm. oblique et transversi*, which in *Lemur* and *Tarsius* cover practically the entire convex surface of the ear cartilage, in *Hapale* form a small zone of muscle bundles, which bridge the fissure between concha and scapha, a cleft known as *sulcus anthelicis transversus sive fissura plicae principalis* (Boas). The plan of the ear musculature in the marmosets is not only simpler than that of *Tarsius* and the Lemuroidea, but it is secondarily reduced through deterioration of the *Mm. obliqui et transversi*, and through the loss of the *M. mandibulo-auricularis*, a muscle which belongs to the original marsupio-placental ground plan (compare Huber, 1918–26) and which is retained as an essential, functioning muscle in the prosimian plan. The marmosets, in contrast to the Prosimiae, share these characteristics with the rest of the Simiae.

The tactile apparatus of facial vibrissae (in figures indicated clipped off) shows a similar arrangement to that of *Tarsius;* however, in addition to the interramal vibrissae the marmosets have lost also the genal vibrissae.

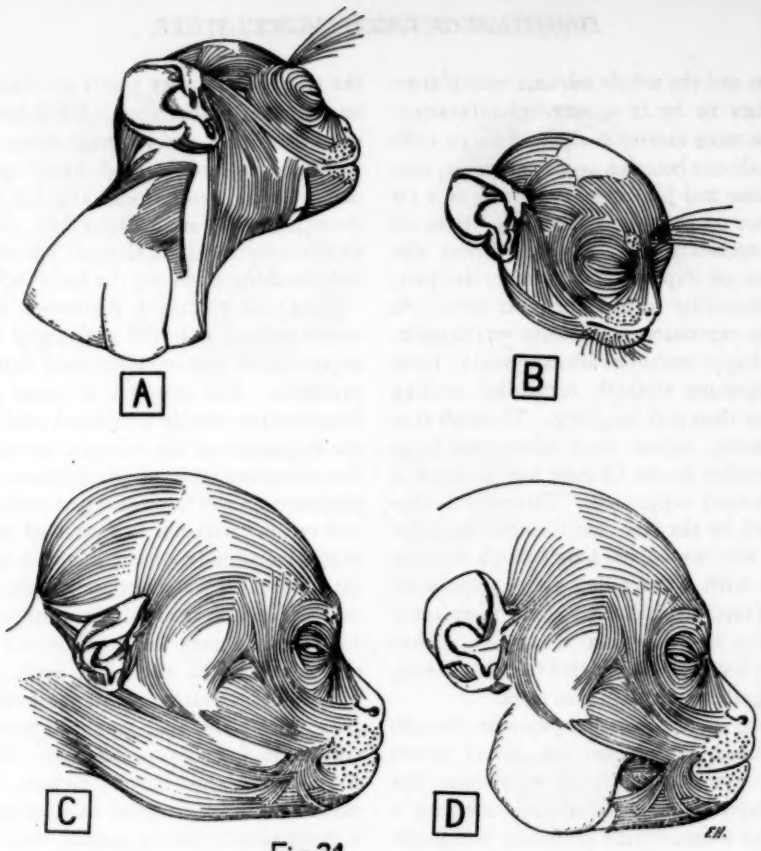

Fig.31

FIG. 31. NYCTIPITHECUS (AOTUS) AND ATELES ATER (SPIDER MONKEY), THE FORMER A PRIMITIVE AND THE LATTER A HIGHLY EVOLVED AND SPECIALIZED REPRESENTATIVE OF THE CEBIDAE, THE SECOND FAMILY OF THE PLATYRRHINES (COLLECTION OF DIVISION OF MAMMALS, U. S. NATIONAL MUSEUM, AND JOHNS HOPKINS ANATOMICAL COLLECTION)

Nyctipithecus (figs. *a* and *b*) is interesting in that it combines primitive characteristics of the Prosimiae and of the lower platyrrhines. In some regards it is more primitive than the Hapalidae, while in others it is intermediate between the Hapalidae and the Higher Cebidae. Note in fig. *a* the primitive extension of the *sphincter colli profundus* and its primitive connection with the preauricular muscle complex and the *M. auriculolabialis (zygomaticus)*. It is also noteworthy that in *Nyctipithecus* the conspicuous supraorbital tactile vibrissae are concentrated in one single bundle over the medial end of the margo supraorbitalis. There they are implanted into a wart-like projection of the skin (fig. *b*), into which bundles of the *M. depressor supercilii*, *M. orbicularis oculi* and *M. frontalis* are inserted. By this characteristic arrangement of the supraorbital vibrissae the Prosimiae, Hapalidae and *Nyctipithecus* contrast with the higher platyrrhines and all the catarrhine monkeys, apes and man, where the Supercilii are found scattered from the lateral end of the supraorbital margin to the glabella (compare e.g., fig. 33: gibbon).

Ateles (figs. *c* and *d*) has the facial musculature evolved to a considerably higher level than *Nyctipithecus*. Through deterioration of the nuchal portion of the platysma the postauriculo-occipital muscle group has become independent of its matrix (compare fig. *c* with fig. *a*). It has settled down on the occiput. The *M. auricularis posterior*, consisting of several slips, has become more independent of the *M. occipitalis* and has shifted its origin closer to the ear cartilage (fig. *c*). In striking contrast to the marmosets and *Nyctipithecus*, the *Sphincter colli profundus* in *Ateles* has dropped out from the plan (fig. *d*); and its derivatives, the muscles of the face, have received further elaboration. The formation of a *M. triangularis*, which overlaps the platysma, is noteworthy (fig. *c*). The orbicularis oris-buccinator group (only partly shown in fig. *d*) has likewise evolved above the stage of the lower platyrrhines. *Ateles* shares these progressive features with other representatives of the higher Cebidae, notably with *Alouatta* (*Mycetes*) and *Lagothrix*, while *Cebus* in some respects is a little more primitive (Ruge, 1887; Schreiber, 1918; Huber).

great complexity of synergetic actions of the various muscle portions of the mimetic muscles of the lips and cheek wall (Lightoller, 1925). According to the diverse languages certain portions of these muscles may be involved more vigorously and more frequently in one language, while in another language other muscle portions may be of greater functional importance. It is hence not unlikely that certain peculiar features of expression of the various human races and of subdivisions of these races, depend on differences in the language. If this assumption should prove correct we may further expect that individuals who acquire a new language and practice this over a long period acquiring facility, should gradually show a change in facial expression about the mouth.

If we progress on the lines which I have here briefly outlined we will, I think, gain a fuller understanding of facial expression with its modifications in the various human races. Here lies a vast, rich field for future research.

VIII. THE UNSETTLED QUESTION OF DEEP SENSIBILITY OF THE FACE. NEW EXPERIMENTS EVIDENCING THE EXISTENCE OF POSTURAL SENSE IN THE MIMETIC MUSCULATURE IN MAN, CONDUCTED TOGETHER WITH MUSCLE PRESSURE SENSE BY THE N. FACIALIS

The pathway for deep sensibility of the face has long been disputed. Through clinical and experimental investigations, Spiller (1906), Ivy and Johnson (1907/08), Davis (1923), and Gerard (1923) came to the conclusion that deep sensibility (pressure, pain) of the face is carried in the *N. facialis* and not in the *N. trigeminus*. One may assume that the deep sensibility here in question is transmitted through sensory facial branches which terminate within the facial musculature. It is to be expected that coëxisting with this "deep facial sensibility" or "muscle pressure sense" there is a sensibility in the deeper layers of the subcutaneous tissue, transmitted through sensory trigeminal branches. Any pressure stronger than a light touch exerted upon the skin over the face would naturally reach the endings of the sensory branches of the *N. trigeminus* in the deeper layers of the subcutaneous tissue, as well as the endings of the sensory branches of the *N. facialis* within the subcutaneously located facial musculature. After elimination of the sensory trigeminus, the deep pressure sense in the facial musculature remains, as demonstrated through the clinical and experimental studies of the above quoted authors, as well as through personal experiments (Huber and Hughson). While in the face "deep skin pressure" sensibility may not be considerable, it surely plays a great rôle in other parts of the body, above all on the palmar and plantar surfaces. This may be deduced from the fact that here the cutaneous nerve branches involved end in complex sense organs, the Pacinian corpuscles, which presumably represent the receptors of "deep skin pressure."

If we exert still stronger pressure upon the skin over the face, this pressure also reaches the sensory nerve endings in the periosteum of the facial part of the skull. No experiments have so far been undertaken to discriminate in the face this "deep, periosteal pressure" from the muscle pressure and the deep skin pressure. It is to be expected that periosteal pressure over the face and anterior part of the cranium is conducted through the *N. trigeminus*, while periosteal pressure over the occipital and mastoid regions should be found through the branches of the *N. occipitalis major* and the corresponding sensory branches of the cervical plexus (*N. occipitalis minor* and *N. auricularis magnus*). Over the vertex, there is probably an

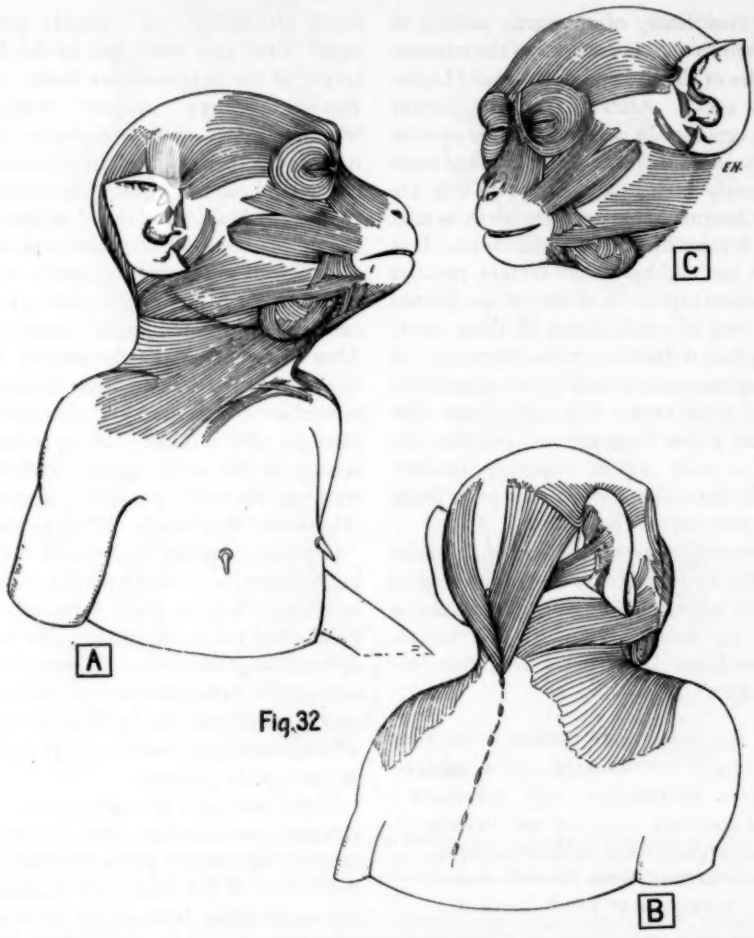

Fig. 32

FIG. 32. PITHECUS (MACACUS) RHESUS, AS A REPRESENTATIVE OF THE LOWER CATARRHINES (CERCOPITHECIDAE) (JOHNS HOPKINS ANATOMICAL COLLECTION)

The facial musculature of the macaque has not quite evolved to the level which the higher platyrrhines have reached. This becomes evident from the fact that the postauriculo-occipital muscle group still largely arises from the nuchal region, where it has retained its primitive relations with the persisting nuchal portion of the platysma (figs. *a* and *b*). The *M. auricularis posterior*, represented by a deeper layer of the postauriculo-occipital muscle complex, has however definitely shifted its origin to the occiput (fig. *b*). In regard to the postauriculo-occipital muscle group the macaque thus exhibits conditions which can easily be derived from the plan characteristic of the lower platyrrhines. The platysma, on the other hand, shows in the macaque modifications which are undoubtedly correlated with the acquisition of the buccal pouch. This pouch is formed by a continuation of the mucous membrane of the cheek wall, lined with a strong muscular coat derived from the *M. buccinator*. It has herniated through the platysma, splitting this muscle plate into an upper and a lower portion (fig. *a*). The buccal pouch now rests upon the lower portion of the platysma subjacent to the skin (figs. *a* and *c*). Anteriorly to the buccal pouch strong crossing bundles of the platysma from the right and left side interlace (fig. *a*). This solid interlacing of platysma bundles below the chin is, no doubt, likewise correlated with the formation of the buccal pouch. Owing to the strengthening muscle coat the buccal pouch can be greatly distended. The temporarily stored food is repelled into the buccal cavity by voluntary contraction of the musculature of the pouch. However, when the pouch has been tightly packed with food and overdistended, the muscle coat of

area of overlap in periosteal sensibility. Since the *M. frontalis*, *M. occipitalis* and the superficial temporal musculature are invariably separated by considerable muscle-free areas over the vertex, periosteal and deep skin pressure could be tested best in the region of the galea aponeurotica, into which the epicranial facial muscles insert.

Besides the superficial skin sensibility, and the three-fold deep sensibility (deep skin pressure, muscle pressure and periosteal pressure) we have to consider the muscle sense (postural sense) in the mimetic musculature. This question likewise remained an open one.

Long ago Charles Bell and Magendie reported that some flattening and other changes in the contour of the face occur after section of the peripheral branches of the *N. trigeminus*. Later Krause (1895, '96), Cushing (1904) and other surgeons observed that following section of the *N. trigeminus* or of its sensory root, or extirpation of the Gasserian ganglion, certain postural deformities in the mimetic musculature may occur. Cushing was the first to ascertain the absence or presence of postural sense in cases of trigeminus section, by the use of the faradic current. According to Cushing's statements his patients were unable to appreciate muscle contraction in the mimetic musculature produced through electric stimulation, unless the twitchings were conveyed to an esthetic area. These observations made plausible the postulate that postural sense from the mimetic musculature is transmitted through the *N. trigeminus*.

Mills (1910), on the other hand, argued that facial movements, while of much importance in expression, nasal respiration, articulation, and a few other well known functions, are probably not to any large degree dependent for their proper performance upon postural sense. The postural sense might, according to Mills, have considerable representation in an afferent system passing with the motor *N. trigeminus*. Nevertheless Mills admitted the probability that there is some postural sense conducted with the facial movements, although this may not be of much importance. Though in his stimulation experiments some observations indeed suggest transmission of muscle sense from the mimetic musculature through the *N. facialis*, Mills states that he was not able fully to convince himself that this sense of contraction was not a result of extrapolar diffusion of very strong current to neighboring areas which were esthetic, or only partly anesthetic. Thus Mills finally came to accept Cushing's conception, which evidently became the prevailing view among the neurologists (compare Kappers, 1920, p. 535).

In view of the uncertain state of the

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the pouch is not sufficiently strong to expel the food. Under such circumstances the animal pokes the food back into the buccal cavity with the aid of the fist. The other representatives of the Cercopithecinae show similar conditions, while the representatives of the Semnopithecinae, the second family of the Cercopithecidae, lack a buccal pouch.

In regard to the *Sphincter colli profundus* and its derivatives, the lower Catarrhines have evolved above the level of the lower platyrrhines. As in the higher platyrrhines, the *sphincter colli profundus* layer has been dropped from the plan of facial musculature, and vestiges of it are only occasionally encountered as individual variations. This holds true for the entire catarrhine branch. The derivatives of the *Sphincter colli profundus* are well developed though not greatly differentiated in the lower catarrhines: The *M. auricularis anterior et superior*, the orbito-auricular musculature, and the *M. frontalis* still form a primitive muscle complex which covers the anterior part of the calvarium (figs. *a* and *c*). Little differentiation has likewise taken place in the musculature of the midface region. There, the powerful zygomaticus muscle mass remained in broad connection with the *M. orbicularis oculi*, and the *M. naso-labialis* forms a continuous muscle plate which covers the whole nose and expands lateralward into the upper lip (fig. *c*). Lateral to the angle of the mouth appears the *M. triangularis* (figs. *a* and *c*), characteristically overlapping the platysma. It has however not yet expanded as far as the lower border of the mandible, as in the higher catarrhines.

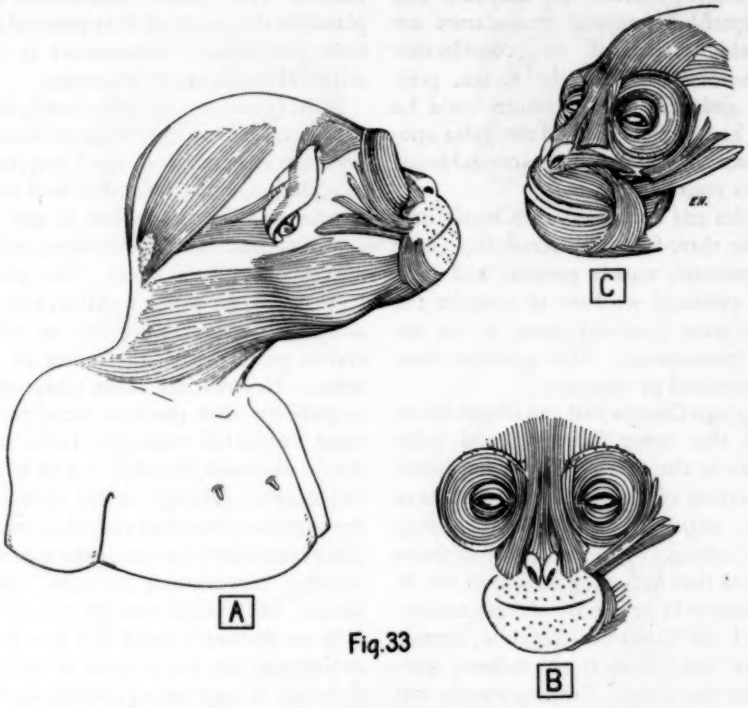

FIG. 33. HYLOBATES PILEATUS (GIBBON) (JOHNS HOPKINS ANATOMICAL COLLECTION)

In their plan of the superficial facial musculature the gibbons show conditions in various regards intermediate between the lower catarrhines and the great anthropoid apes and man. This is clearly seen in the arrangement of the postauriculo-occipital musculature and its relation to the deteriorating nuchal portion of the platysma. The muscles of the face proper, the derivatives of the *sphincter colli profundus*, show primitive conditions combined with strikingly progressive features, which lift the gibbons above the lower catarrhines: the *M. frontalis* is partly set off from the orbito-auricular muscle complex (figs. *a* and *c*). Noteworthy is the indication of a separation of the *M. naso-labialis* into three portions, i.e. two bilateral *Mm. levatores labii superiores*, and a middle unpaired portion, which extends from the glabella downward over the entire back of the nose to be inserted below into the alae nasi (fig. b). This middle portion evidently corresponds to the musculature which in man gave rise to the *M. procerus nasi sive depressor glabellae* and to the very variable, inconstant vestiges represented by the *Mm. dilatatores narium ant. et post.* and the *M. apicis nasi*. Between the three portions just described there are more feeble intermediate muscle bundles. Note that in the glabellar region the three portions remain as one, having preserved the broad connection with the *M. frontalis*. This broad secondary fusion of portions of the supraorbital and infraorbital muscle complexes occurs in the lower primates (compare fig. 29*d*, 30*d*, etc.). It persists throughout the "ascending scale of primates" up to man (compare Huber, 1926/27).

The *M. triangularis* in the gibbon has extended further downward when compared with conditions found in the lower catarrhines. It reaches the lower border of the mandible. The orbicularis-buccinator group (partly shown in fig. *c*), although more highly evolved than in the lower catarrhines, has not attained the complexity of the corresponding muscle group of the great anthropoid apes and man. Strangely primitive among the derivatives of the *pars oris, sph. colli. prof.*, is the *M. maxillo-naso-labialis* (fig. *c*), which has hardly evolved above the stage of the primitive simian plan, while the same cannot be said of the lower catarrhines.

Hylobates (gibbon) and *Symphalangus* (siamang), the two genera of the Hylobatidae, show a very similar arrangement of the superficial facial musculature. In some regards, however, *Symphalangus* stands a little higher than *Hylobates* (compare Ruge, 1911).

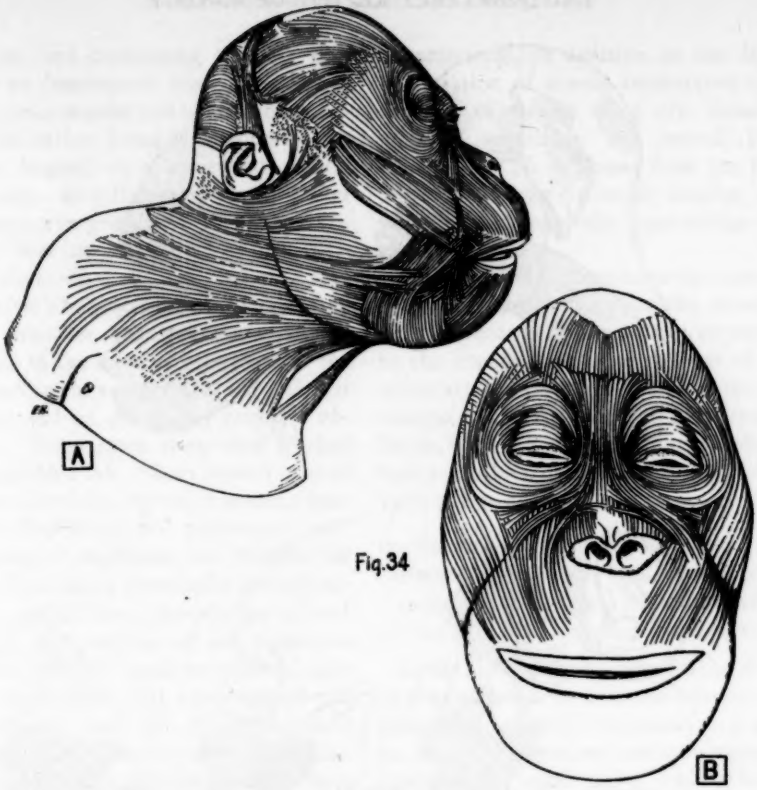

Fig. 34

FIG. 34. HALF GROWN ♂ ORANG (PONGO) (JOHNS HOPKINS ANATOMICAL COLLECTION)

The plan of the superficial facial musculature of the orang shows striking deviations from the ground plan of the other two great anthropoid apes (chimpanzee and gorilla) and man. The platysma is peculiar through its bony attachment with a slip to the acromion (fig. *a*). The postauriculo-occipital muscle group covers the occiput like a little cap; it sends a muscle slip to the auricle, and there is an additional, deep *M. occipitalis* (not shown in figure). The most peculiarly shaped *M. auricularis superior* ascends as a rather narrow band as far as the height of the vertex, while a small slip of it has extended a short distance downward in front of the ear. This *M. auricularis superior* belongs entirely to the postauricular muscle group, as shown by its nerve supply (Huber, in disagreement with Ruge and Popowsky), while, on the other hand, the *M. auricularis ant. et sup.* of chimpanzee, gorilla and man represents a fusion of a postauricular with a preauricular portion. The *Mm. auriculares proprii* of the orang, which have received little attention by previous investigators with the exception of Ruge, are further deteriorated than those of the chimpanzee, gorilla and man. Traces of all of them were, however, detected in the specimen investigated by the author, in contrast to the specimen of Ruge.

Among the derivatives of the *Sphincter colli profundus* (figs. *a* and *b*) the well developed, but not further subdivided orbito-auriculo-frontal muscle complex covers the anterior half of the calvarium (fig. *a*). The preauricular portion is reduced to a tendinous plate, which does not reach the ear,—this in striking contrast to the chimpanzee, gorilla and man. The zygomatico-orbital muscle plate of the orang is without attachment to the zygomatic arch. It is still in broad connection with the *M. orbicularis oculi*. The *M. triangularis* is very powerfully developed, and differs in proportions from that of the chimpanzee, gorilla and man. In the glabellar region (fig. *b*) the muscle corresponding to the *M. procerus nasi sive depressor glabellae*, is inserted above with superficial muscle bundles into the subcutaneous tissue; with its deep bundles, however, it remains continuous with the *M. frontalis*.

The orbicularis oris-buccinator group (not shown in figures) is far more complex than in the gibbons and the lower catarrhines; but it differs fundamentally in its architecture from the similarly complex musculature of the chimpanzee, gorilla and man.

The findings of previous investigators (Ruge, Popowsky, Sullivan and Osgood, Lightoller) give evidence that the features here emphasized as striking peculiarities of the orang, are not mere individual variations but really belong to the ground plan of this animal.

Fig. 35

FIG. 35. YOUNG ♂ CHIMPANZEE (PAN) (COLLECTION OF THE DIVISION OF MAMMALS, U. S. NATIONAL MUSEUM)

The plan of the superficial facial musculature of the chimpanzee closely corresponds with that of the gorilla (fig. 36). Both chimpanzee and gorilla share with man, not only a common ground plan but also similarly directed evolutionary trends: there exists on one hand, a striking tendency towards reduction of the superficial muscles of the temporal and occipital regions and structural as well as functional deterioration of the entire ear musculature (figs. *a* and *c*), while the musculature of the face proper tends towards fuller development and further differentiation. However, as to structural differentiation, but especially in regard to functional perfection of the musculature of the face, man excels by far the great anthropoid apes (orang, chimpanzee and gorilla).

In figure *c* the formation of a *M. corrugator supercilii* with firm origin from the frontal bone is noteworthy. This formation is characteristic of chimpanzee, gorilla and man. A corresponding deep muscle portion, though not detached from the *M. frontalis*, exists also in the orang, while the gibbons and lower catarrhines lack such a differentiation. Common to all, however, is the *M. depressor supercilii*, which has been retained from the primitive primate ground plan. This is the muscle which in the lower primates controls the supraorbital tactile vibrissae (compare figs. 28, 29, 30 and 31*a* and *b*).

Figs. 35*c*—*e* show the derivatives of the *pars oris sph. colli profundi*. This musculature has reached a high complexity which cannot be brought out fully in this short discussion and with only a few figures (compare further Virchow, 1915). A comparison of figure 35*c* with figure 33*c* of the gibbon shows that the *M. maxillo-labialis* in the chimpanzee has shifted its origin higher up on the maxilla. Through this it became a *M. levator labii superioris proprius*. This is characteristic not only of the three great anthropoid apes and man, but also of the lower catarrhines; while the gibbons, as already pointed out, have retained more primitive conditions. The *M. nasalis* of the chimpanzee (figs. *a*—*d*) shows a similar arrangement to that in gorilla and orang, in contrast with conditions found in man. The *M. mentalis* (fig. *e*) is seen in close, primitive relation to the *M. buccinator* (Huber), while a deep bundle of the platysma inserts in the immediate neighborhood, a finding which misled Ruge to derive the *M. mentalis* from the platysma.

question, and considering the fact that efforts to demonstrate muscle spindles in the mimetic muscles had been without success, the author found it worth while to submit himself to a somewhat painful procedure. In collaboration with Walter Hughson, a surgeon, the following experiments were undertaken: With the unipolar electrode there were determined in the author's face the sites of the individual facial branches from which a definite response of the mimetic muscles over the forehead, in the supraorbital and glabellar regions, and on the cheeks could be obtained. These spots were then marked with indelible ink. Keen appreciation of contraction of the responsive mimetic musculature facilitated this preliminary test.

In order to determine now whether the contraction of the electrically excited mimetic muscles was indirectly appreciated through the pathway of the cutaneous branches of the *N. trigeminus* over the areas under observation, the *rami frontalis* and *supraorbitalis*, and the *N. infraorbitalis trigemini* were blocked with novocain. After complete anesthesia of the respective areas, the previously mapped out individual facial branches were alternately stimulated as in the preliminary test. And in every instance the author with closed eyes was able not only to tell, without delay, when muscle groups or muscle portions under stimulation were contracting, but also to name the individual facial branches which must have been electrically stimulated in order to bring about the appreciated contraction of the respective muscle group or muscle portion.

These experiments give ample evidence that we have indeed in the mimetic musculature muscle sense, which is conducted together with the muscle pressure sensibility, by the muscle branches of the *N. facialis*. It is likely that under normal circumstances, in addition to the direct appreciation of muscle contraction with the aid of muscle sense (*N. facialis*), postural sensations are carried back through the *N. trigeminus* from the skin when the latter is under tension and wrinkled through the contracting mimetic muscles.

It remains for future investigations to detect in the superficial facialis musculature the sensory organs which correspond to the muscle spindles of the rest of the voluntary musculature. More recent investigations along this line by Olive C. Smith, with the methylene blue technique, have so far been negative (compare Hines, 1927, p. 159, 167).

IX. REFLEX CONNECTIONS BETWEEN THE SENSORY TRIGEMINUS FIELD AND THE FACIAL MUSCULATURE. ANASTOMOSES OF THE N. FACIALIS WITH OTHER NERVES

Lastly, brief consideration will be given to the functional connections between the sensory field of the *N. trigeminus* (skin, conjunctiva of the eyes, mucous membranes of nose, lips and buccal cavity) and the facial musculature. With the expansion of the superficial facial musculature over the entire face in mammals (chapter I) and the simultaneous evolution of the sensory field of the *N. trigeminus* (chapters IV, V, VI), functional connections were established between the two fields, which do not exist in vertebrates below the mammals. Those subdivisions of the motor facial nucleus which represent the primary motor centers for the superficial facial musculature (ear muscles, muscles of the face: vibrissae moving muscles, muscles of the snout, lips and cheek wall, and above all the *M. orbicularis oculi*, the protecting muscle of the eye) were brought under the influence of the sensory trigeminus. Thus new arcs were established for reflexes, among them such vitally important ones as the suckling

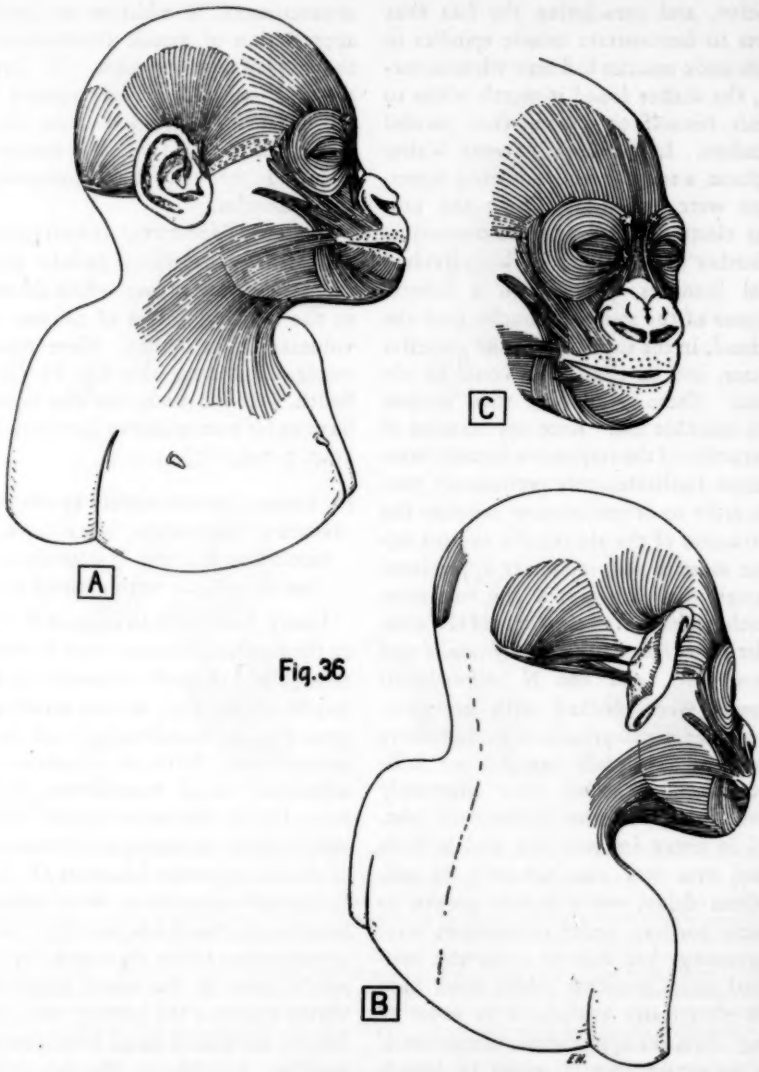

Fig. 36

FIG. 36. YOUNG ♀ GORILLA (G. GORILLA) (COLLECTION OF DEPARTMENT OF COMPARATIVE ANATOMY, AMERICAN MUSEUM OF NATURAL HISTORY, NEW YORK)

The figures show the superficial facial musculature on a plan which is characteristic of the gorilla, chimpanzee and man. Through the loss of the nuchal portion of the platysma the postauriculo-occipital muscle group has become completely isolated in the occipital region (figs. *a* and *b*). The *M. occipitalis* (fig. *b*) arises from the linea nuchae superior. There is a considerable space between the occipital musculature of the two sides. The *M. auricularis posterior*, still in close relation with the *M. occipitalis*, is represented by several slips which insert into the ear cartilage. The muscle is at the origin reduced to a tendinous band. This gives evidence that the evolutionary tendency of the extrinsic postauricular musculature is to shift closer to the ear. The same trend is clearly seen also in the chimpanzee (fig. 35*a*) and man (compare succeeding figures). The range of in-

reflex, and the ocular reflex. In connection with the latter it may be stated that the effective reflex closure of the eyelids with the aid of the *M. orbicularis oculi* rendered more or less superfluous the nictating membrane, a phylogenetically older eye protecting structure, which in certain mammals, including the Primates, has become reduced to a mere vestige.

Throughout the orders of mammals some of the muscle branches of the *N. facialis* anastomose with branches of the *N. trigeminus* as well as with branches of the cervical plexus. This fact has led a series of previous authors (Leche, Westling, McKay, Kohlbrugge, v. Bardeleben, Eisler, Edgeworth, Poirier and Charpy, *et alii*) to assume that through such anastomoses the superficial facial musculature receives an additional motor supply. Although such an assumption could be discounted on the basis of comparative anatomical and embryological investigations, which had afforded convincing evidence that the superficial facial musculature represents a genetic entity, a muscle territory under the exclusive domain of the *N. facialis* (chapter I), it was important to give supplementary proofs of it to those who were sceptical of data from comparative anatomical and embryological investigations. It is impossible to untangle by purely morphological methods of investigation the complex anastomoses of the *N. facialis* with the branches of the *N. trigeminus* and with nerves of the cervical plexus. Here, the experimental method alone could bring a satisfactory solution.

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dividual variations with transitions from primitive to more progressive conditions is very considerable in all three types. Moreover, there is a conspicuous tendency towards deterioration of this muscle group. It may be added that ear movements in the gorilla and chimpanzee have been noted to be almost as rare as in man. In the case of the chimpanzee shown in figure 35*a*, contrasted with the gorilla of figure 36*b*, the postauriculo-occipital musculature has reached an extreme degree of regression, the *M. auricularis posterior* being represented in this case by short muscle slips which have settled down very close to the ear, while the much reduced vestigial *M. occipitalis* remained isolated in its original position. There have been cases reported where the *M. occipitalis* of the chimpanzee was completely deteriorated.

The orbito-auricular muscle complex of the gorilla (fig. 36*a*), although still with primitive extension in this specimen (compare case of Ruge, 1887a), is in part reduced to a tendinous plate, intermediate between the *M. frontalis* and the *M. auricularis ant. et sup.*

Among the muscles of the face proper (figs. 36*a* and *c*) conditions of the zygomatico-orbital muscle mass are noteworthy. While this muscle mass has retained a broad connection with the *M. orbicularis oculi*, the lateral portion of it, which in the chimpanzee (fig. 35*a*) has settled down on the zygomatic arch, is in the gorilla clearly set off as a well defined "*M. zygomaticus.*" This was found also in other specimens of gorilla dissected by previous authors (compare e.g., Ruge, 1887a). That the *M. zygomaticus* of the gorilla, however, should not be considered fully homologous with the human zygomaticus muscle, becomes evident from a comparison with primitive and progressive stages of zygomaticus formations in man. While in the White race the *M. zygomaticus* in a prevailing percentage of cases is a distinct muscle with bony origin from the zygoma, in other races as a rule only deep bundles of the zygomatico-orbital muscle mass have settled down on the zygomatic arch, while the bulk of superficial bundles are anchored in the subcutaneous tissue of this region, often extending further back in the direction of the ear. The well defined *M. zygomaticus* of the White may be derived from such a more primitive arrangement through loss of the superficial zygomatico-orbital bundle mass and persistence of the deep muscle portion attached to the zygoma. Various intermediate stages illustrating such a transformation are found as individual variations in the White.

The *M. triangularis* in gorilla and chimpanzee is of similar proportions to that of man; it is fixed with its base to the platysma, but has not yet become attached to the mandible, as in the latter.

In both gorilla and chimpanzee, as well as in occasional cases of man a group of platysma bundles cross the *M. triangularis* at the junction of this muscle with the *M. caninus* to become inserted into the angle of the mouth. This muscle portion, often referred to as *M. risorius*, is not a real Risorius. The true *M. risorius Santorini*, usually composed of deviating marginal bundles of the *M. triangularis*, is peculiar to man. That deviating bundles of the *M. zygomaticus*, or of the platysma, or of both, may join or even replace the true *M. risorius Santorini*, is well known to those who have studied this extremely variable formation in a larger series of human bodies.

The nasal musculature shows differences in the gorilla, chimpanzee and man, according to the conspicuous differences in the formation of the nose of the three types. In man this musculature is more highly evolved and developed on a somewhat different plan than in the gorilla and chimpanzee, which show greater resemblance to one another. Their plan of nasal musculature is similar to that of the orang.

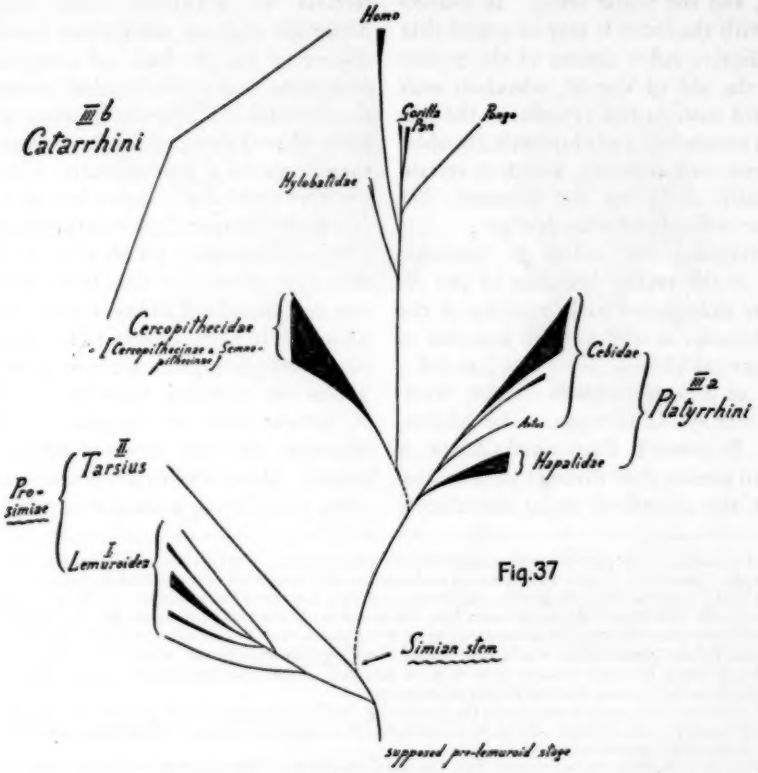

FIG. 37. SCHEME REPRESENTING THE AUTHOR'S CONCEPTION OF THE PROBABLE GENETIC RELATIONSHIP OF THE LIVING PRIMATES, BASED ON INVESTIGATION ON THE FACIAL MUSCULATURE (No consideration is given to the time element, nor are the adaptations to different habitats taken into account)

Lemuroidea and Tarsoidea are shown as divergent branches of a common prosimian stock. The separate lines of the lemuroid branch represent the existing divergent lemuroid types, which are to be considered more closely related to each other, in contrast to the independent branch leading up to modern *Tarsius*.

The Simian stem is derived from an early, generalized tarsioid form, which first gave rise to primitive platyrrhine monkeys. From these early platyrrhine forms evolved the various groups of the modern platyrrhines, while one type, it is thought, gave rise to the catarrhines. The indicated subdivision of the platyrrhines into only two families, the Hapalidae and the Cebidae, should not be considered final: While the various genera of the Hapalidae form a natural group, there are various primitive intermediate types (e.g. *Aotus*) included within the Cebidae, which may possibly represent distinct families.

The catarrhine branch is shown splitting up early into the Cercopithecidae and the higher catarrhines. Within the family of the Cercopithecidae no further consideration is given to the genetic relationship of the subfamilies of the Cercopithecinae and Semnopithecinae and their genera. The genetic relation of the members of the anthropoid-human branch is further considered in the next figure.

A recent study by Michelsson (1921), and more extensive investigations by the author in collaboration with Hughson (electrical stimulation of the first five cervical nerves, the *N. trigeminus* and the *N. facialis*, and cutting of the peripheral branches of the *N. facialis* with consequent loss of function and degeneration of the corresponding facial muscles) have given conclusive evidence that the anastomosing

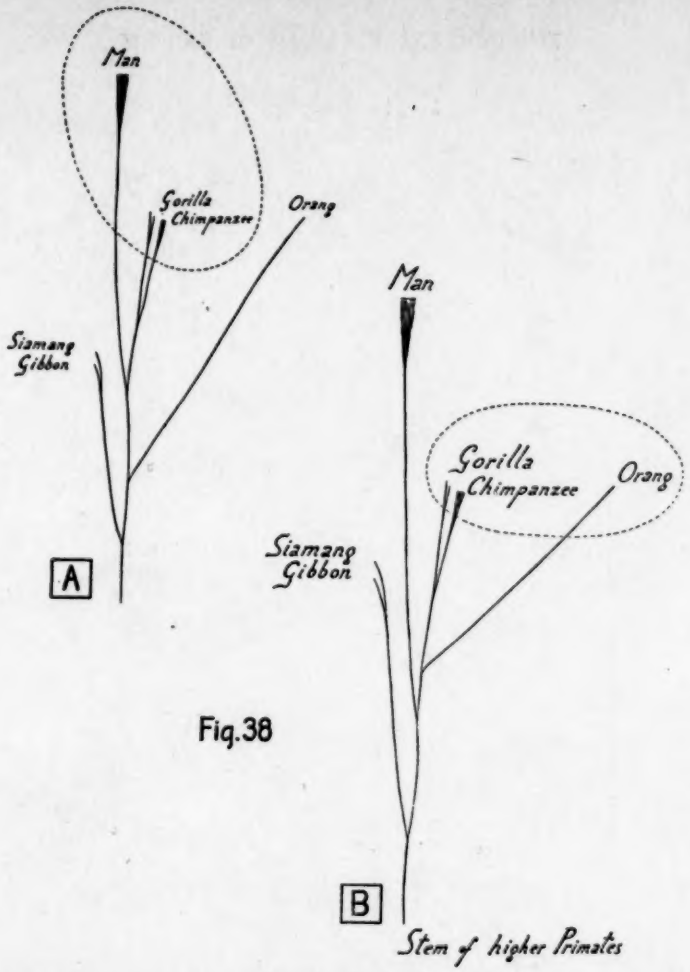

Fig. 38

FIG. 38. SCHEME REPRESENTING THE AUTHOR'S CONCEPT OF THE GENETIC RELATIONSHIP OF THE LIVING HIGHER PRIMATES

The gibbons, having undoubtedly early branched off from the common anthropoid-human stem, have, except for the extreme specializations in connection with their brachiating habits, preserved a more primitive ground plan compared with the great anthropoid apes. In a series of features they are intermediate between the lower catarrhines, on one side, and the great anthropoid apes and man on the other. While thus, judged by the findings on the facial musculature as well as on other organ systems, there can be little doubt about the position of the gibbons, the genetic relations between the orang, and the chimpanzee and gorilla, and the relation of man to the great anthropoid apes appear more problematic. From the fact that the orang, in regard to facial musculature and other organ systems, differs so widely from the chimpanzee and gorilla, while the latter two share with man a common ground plan of facial musculature and strikingly similar evolutionary tendencies within this muscle field, one may be tempted to derive man directly from the line leading up to the chimpanzee and gorilla and to separate, on the other hand, the orang from the chimpanzee and gorilla, as indicated in fig. 38*a*. However, giving weight to the likeness of the three great anthropoid apes in many features of the various organ systems, and considering their likeness in general appearance and psychology, one can hardly separate them. It therefore seems more reasonable to derive man from the anthropoid-human stem before the three great anthropoid apes had evolved from this stem, as indicated in fig. 38*b*. According to this second scheme the orang would, after an early departure from the great anthropoid stem, have sidetracked with high evolutionary trends of his own, while chimpanzee and gorilla evidently stayed closely together. And parallel to them developed man with evolutionary trends innate to all three.

Although the author in the text conservatively referred to the various races of man, it would seem to him justifiable to value these "races" as distinct species, thus applying the same measure as generally applied in evaluating the various types of chimpanzees and gorillas.

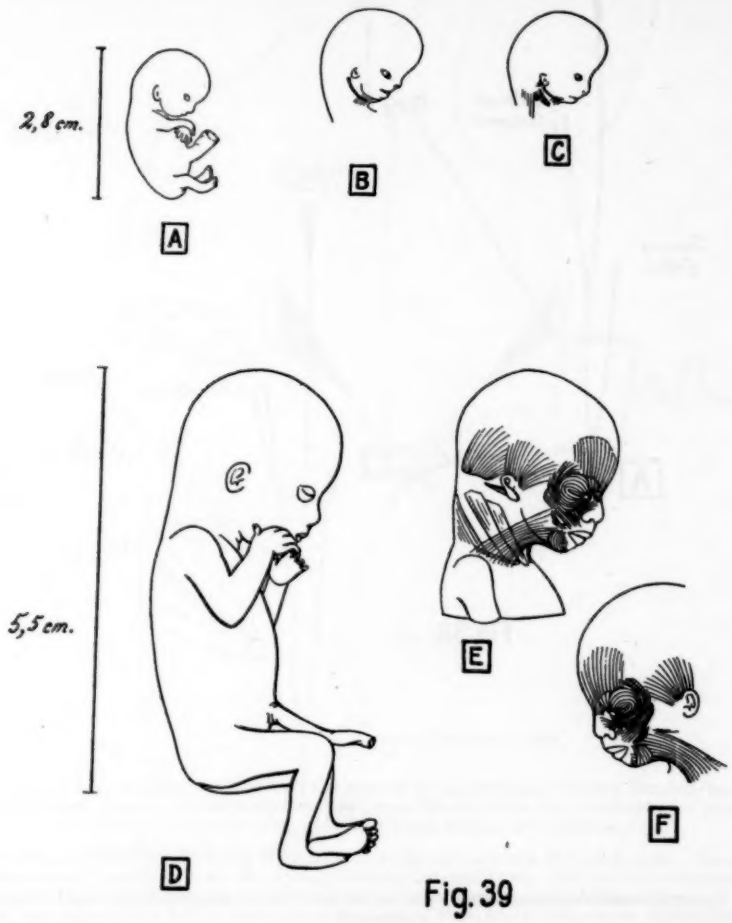

Fig. 39

FIG. 39. EARLY STAGES IN THE EMBRYOLOGICAL DEVELOPMENT OF THE MIMETIC MUSCULATURE OF MAN

A and *C*. *Human embryo* of the end of the *2nd month*, 2.8 cm. crown-rump length (No. 1460 of the Collection of the Carnegie Laboratory of Embryology, Baltimore).

B. The same stage, after Popowsky (1895): anlage of the platysma with its innervation through the *N. facialis*. According to Popowsky there are in this stage no mimetic muscles besides the neck portion of the platysma. However, the author could, in his specimen (compare fig. *c*) with the aid of the dissecting microscope demonstrate the presence of the *M. auricularis posterior*. This muscle was even further advanced in development than the barely recognizable platysma. It showed a close, primitive relation to the *M. biventer posterior* of the deep facial muscle group, which was still further advanced in its differentiation, about to the degree of the well defined anlagen of the sterno-cleido-mastoideus and trapezius muscles. Microscopic studies by Zuckermann-Zicha (1925) moreover give evidence that around this stage the first histological differentiation of muscles in the face (*M. orbicularis oculi*) take place. It is interesting to see that during the embryological development certain groups of the facial musculature precede in their differentiation other groups. The critical period of development and differentiation of the mimetic musculature is evidently between the 2nd and 3rd month of fetal life, as seen from the following figures.

D—*F*. White male fetus of the end of the *3rd month*, 5.5 cm. sitting height (No. 4808 of the Collection of the Carnegie Laboratory of Embryology).

branches in question, of the *N. trigeminus* and cervical nerves with the *N. facialis*, are not motor (compare Huber, 1924; Huber and Hughson, '26).

Renewed claims by Edgeworth (1928) that the platysma in the opossum is innervated by additional branches from the cervical plexus, have lately been disproven through experiments repeated by W. K. Smith (unpublished).

The question now arises, what significance the anastomoses under consideration do have, motor function to the facial musculature having been definitely excluded. The author has hitherto been inclined to consider these anastomoses as mere topographic relations. It was thought that certain sensory branches of the *N. trigeminus* and nerves of the cervical plexus ramifying in the same areas where the muscle branches of the *N. facialis* ramify, came in some places to lie so close together with the latter that they were subsequently bound together by common connective tissue sheathes. After a joint journey, it was assumed, the sensory branches of the trigeminal and cervical nerves would separate again from the muscle branches of the *N. facialis*, the various nerve elements finding thereafter the tissue which they were destined to supply (Huber, 1922–23, p. 384–386). This concept is, however, open to criticism until adequate experimental data are available, which definitely exclude functional relations. There is a possibility that by the way of the anastomoses of these cutaneous branches of the *N. trigeminus* and cervical nerves to the muscle branches of the *N. facialis*, the blood vessels within the superficial facial musculature receive their vaso-motor supply.

SUMMARY AND CONCLUSIONS

In this paper comparative anatomical, racial anatomical and embryological studies on the facialis musculature, and studies on the cutaneous field of the *N. trigeminus* are correlated with the data obtained from neuro-physiological investigations.

Although in lower vertebrates up to the Sauropsida the *facialis musculature* is but of moderate extension, it has in mammals attained a unique development. After having become completely separated from the deep facialis musculature, the superficial facialis musculature expanded over the whole head and face.

The Monotremes developed the super-

This fetus had been recovered from a miscarriage, and under special care survived for half an hour. The author thus had an opportunity to stimulate with the unipolar method the various branches of the *N. facialis*. The mimetic muscles responded by definite contraction to the electrical stimuli of the corresponding muscle branches. Fine wrinkling of the delicate skin in the various regions of the face, and movements of the ears were clearly noticeable. This experiment thus revealed the fact that the motor nerves are capable of carrying electrical impulses to the muscles at an earlier stage than previously demonstrated by Minchowski (1928), who found the peripheral nerves responsive from the fourth month on. The experiment moreover gave evidence that, contrary to the statements of Popowsky (1895), the mimetic musculature at the end of the 3rd month is already regionally differentiated. This was subsequently corroborated by detailed, careful dissection of the fetus, which had been preserved in Bouin's fluid. The findings are illustrated in figs. 39*e* and *f*. Note, by careful comparison of the right and left aspect represented in these two figures, that already at this early stage variations on the right and left sides are recognizable. These asymmetries become more marked in the following stages, as the structures receive more elaborate differentiation. While the fixation in Bouin's fluid proved very satisfactory for detailed dissection under the binocular lens and dissecting microscope, it was impossible to see in this fetus the characteristic gelatinous, half transparent consistence of the mimetic muscles, or to demonstrate the various phases of differentiation in which the given muscle groups appear at this stage. These characteristics, however, were clearly noted in a formalin preserved specimen of the same stage dissected by the author side by side with the one preserved in Bouin's fluid.

Preliminary parallel investigations, which the author has carried out on embryo and fetal pigs, suggest that on account of the different rate of differentiation of the various muscle groups the study of the embryological development of the muscle system may eventually prove very helpful in correlating the corresponding developmental stages in the mammalian series up to man.

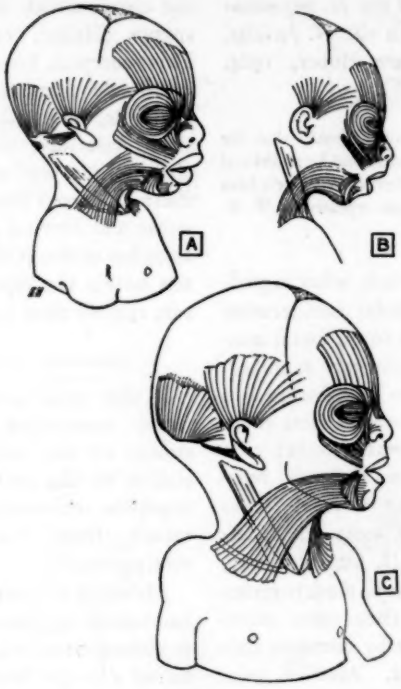

Fig. 40

FIG. 40. FURTHER DEVELOPMENT OF THE MIMETIC MUSCULATURE AND RACIAL DIFFERENTIATION IN NEGRO AND WHITE FETUSES OF THE 4TH AND 5TH MONTH

Male Negro fetus (*A*) of the end of the 4th month (No. 1524, 13.2 cm. sitting height) compared with male White fetus (*B*) of the end of the 4th month (No. 3047, 12.8 cm. sitting height) and male White fetus (*C*) of the 5th month (No. 4914, 17.9 cm. sitting height), all three of the collection of the Carnegie Laboratory of Embryology.

Racial differences show up as early as the 4th month, where the mimetic musculature of the Negro (*A*) is more coarsely bundled, and the individual muscles appear more compact when compared with those in the White (*B*). Conspicuous is the heavy zygomaticus muscle mass which is directly continuous with the *M. orbicularis oculi*. Contrasting strikingly with the Negro the author found in the 4 month White fetus (*B*) a well defined *M. zygomaticus*, which had settled down on the zygomatic arch and which at its origin was completely separated from the muscle portion intermediate between the *M. zygomaticus* and the *M. orbicularis oculi*. The entire mimetic musculature in this White fetus was more delicately bundled, and the individual muscles were of a more gracile type.

Again in the 5 month White fetus (*C*) the *M. zygomaticus* was represented by a well-defined muscle which was completely set off from the *M. orbicularis oculi*, although the marginal bundles of the latter overlapped the *M. zygomaticus* at its origin. In addition, there was present a well defined caput zygomaticum of the *M. quadratus labii superioris*.

In general it may be stated that in both Negro and White up to the end of the 5th month the mimetic musculature is of gelatinous, half transparent consistence while the subjacent skeletal muscles are considerably further developed and more compact. This is indicated in all three figures, where the *M. sterno-cleido-mastoideus* and the clavicle are seen shining through the delicate platysma plate.

ficial facialis musculature along their own line, on a ground plan which is distinctly different from the common marsupio-placentalian ground plan. Notable dif-

FIG. 41. SUBSEQUENT STAGES OF DEVELOPMENT OF THE MIMETIC MUSCULATURE IN 3 MALE NEGRO FETUSES OF 4½, 6 AND 7 MONTHS (*A*. No. 4067, 15.7 cm. sitting height; *B*. No. 2397, 24.3 cm. sitting height; *C*. No. 2590, 26.3 cm. sitting height; all three of the Collection of the Carnegie Laboratory of Embryology).

These fetuses were dissected side by side with corresponding stages of the White. Again the Negro characteristics were found well expressed: The entire mimetic musculature appeared more coarsely bundled, and the individual muscles were more compact as compared with the White. There was a lack of differentiation, especially in the musculature of the mid-face region. Note in all three that the massive *M. zygomaticus* is continuous with the muscle bundles which intermediate with the *M. orbicularis oculi*. Only the deep bundles of the zygomaticus muscle mass have gained bony attachment to the zygoma, and there is no caput zygomaticum differentiated. The large size of the *M. orbicularis oculi* is also noteworthy. The proportions of this muscle moreover differ from those of the White. It is the supraorbital portion which exceeds in width that of the infraorbital portion. In the White it is just the reverse.

While in the fetus of 4½ months the mimetic musculature was still of gelatinous, half transparent consistence —note the *M. sterno-cleido-mastoideus* and the clavicle shining through the platysma plate—there was already an indication of reddish-brown coloring to be noticed in the postauriculo-occipital musculature. The tendinous portion of the *M. occipitalis* was thus more clearly set off from the muscular portion. As mentioned before, this muscle group somewhat precedes in structural differentiation the other groups of the superficial facial musculature. In the following stages of the 6th and 7th month (figs. *b* and *c*) the entire facial musculature has lost its gelatinous, transparent appearance and is more compact. The proportions of the individual muscles also have become more like those of the new-born, which are largely like those of the adult (compare with figs. 42 and 44*a*).

Fig. 42

FIG. 42. NEW-BORN NEGROES, FEMALE (A) AND MALE (B AND C), OF THE COLLECTION OF THE CARNEGIE LABORATORY OF EMBRYOLOGY, SHOWING AS THE PRECEDING FIGURES, THE NEGRO CHARACTERISTICS, AND IN ADDITION SOME NOTABLE INDIVIDUAL VARIATIONS

Individual variations are very numerous in the superficial facial musculature. They appear early in fetal life, as seen from the previous figures, and when once laid down they naturally persist to adult life. Many of them can only be satisfactorily explained on an evolutionary basis. Note (e.g., in fig. *b*) the primitive connection between the platysma and the postauriculo-occipital muscle group. Such vestiges of the nuchal portion of the platysma are occasionally encountered in the various human races, including the White. They refer far back to our primate ancestry. A last vestige of the nuchal portion of the platysma usually isolated in the occipital region is the *M. transversus nuchae*, traces of which are, in one form or another, almost constantly found in man up to the adult stage (note this little muscle in fig. 42*b* and compare following figures). The percentage of occurrence of such vestiges is in reality much higher than usually quoted in tabulations.

The extension of the platysma further down over the upper part of the chest (fig. 42*b*) is a progressive feature in the "ascending scale of the primates." It is characteristic of the great anthropoid apes and man. In man the platysma plates of the two sides are usually far apart below (fig. 42*c*). Above, they join just below the chin, this in contrast to the findings in the great anthropoid apes. Lower crossing of the platysma plates in the regio mediana colli, occasionally encountered as individual variations, seems to be more frequent in the Negro.

In figs. 42*a*—*c* there may be noticed a primitive extension of the superficial musculature over the temporal region; however, the *M. frontalis* shows the tendency to become set off from this muscle complex. The zygomaticus muscle mass is undifferentiated and remains in broad primitive connection with the *M. orbicularis oculi*, as in the previous stages of the Negro. The *M. triangularis* is fixed with its base to the mandible. Derivatives of the *M. triangularis* present, are the *M. risorius Santorini* and the *M. transversus menti*.

Variation studies give evidence that the evolution of the human facial musculature is still going on with the trend towards fuller differentiation, as emphasized in the text of chapter VII. In the White this process of evolution has apparently progressed further than in other races (compare following figures).

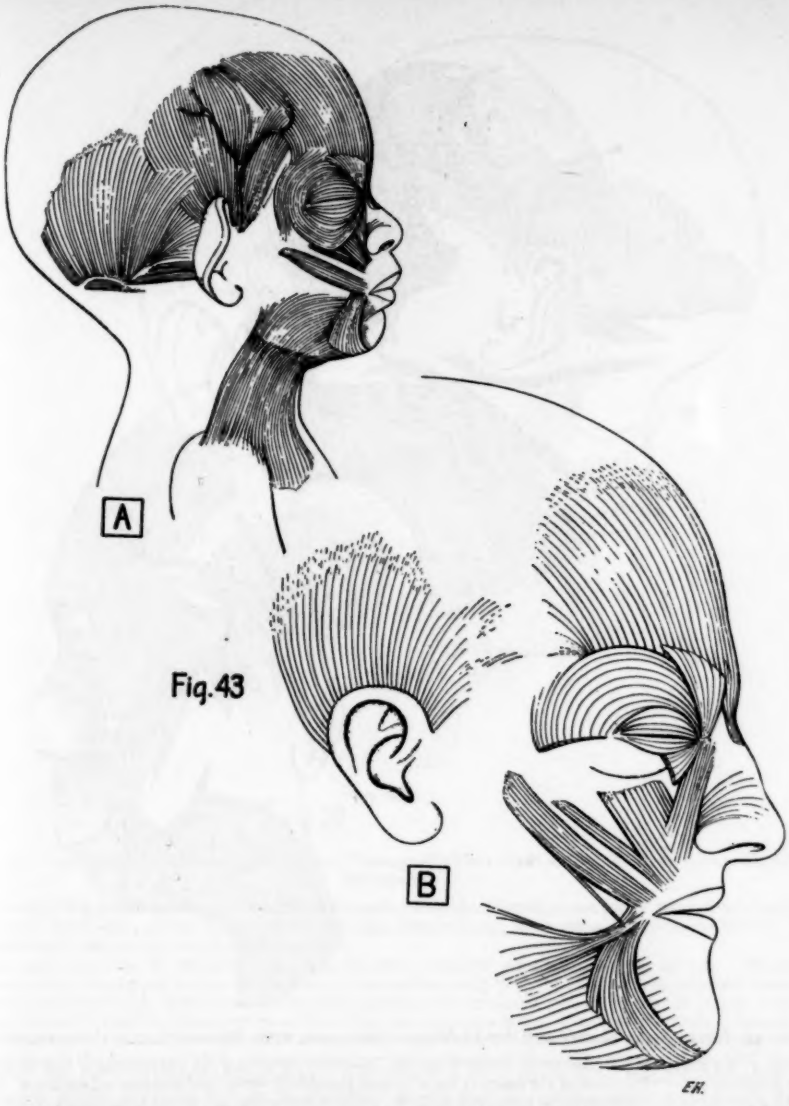

Fig. 43

FIG. 43. ADULT WHITE, CONTRASTED WITH A NEW-BORN WHITE (new-born male of the Collection of the Carnegie Laboratory of Embryology; adult male dissected in the Anatomy of the University of Zürich, Switzerland)

It has already been emphasized that the mimetic musculature of the White is, as a rule, more delicately bundled, less powerfully developed and of lesser extent; but further differentiated if compared with the Negro.

While in the new-born White (fig. *a*) the superficial musculature of the temporal region still shows a primitive extension similar to that in the Negro new-born of fig. 42, it is far reduced in the adult White shown in fig. *b*. Through such reduction the *M. frontalis* became completely separated from the *M. auricularis anterior et superior*. This involution of the muscle complex of the temporal region is part of the postnatal development. Not infrequently however this musculature persists in the adult. All possible intermediate stages may be encountered as in individual variations in the White.

In the mid-face region (figs. *a* and *b*) the *M. zygomaticus* with definite attachment to the zygomatic arch is clearly set off from the *M. orbicularis oculi*, and there is a distinct *M. zygomaticus minor* present, likewise with bony attachment to the zygoma. The latter muscle joins, as caput zygomaticum, the caput infraorbitale and caput angulare to build the "*M. quadratus labii superioris*" of the B. N. A. terminology. This further differentiation of the musculature of the mid-face region is encountered in a prevailing percentage of the White race. It makes its appearance early in fetal life, as seen from previous figures (figs. 40*b* and *c*).

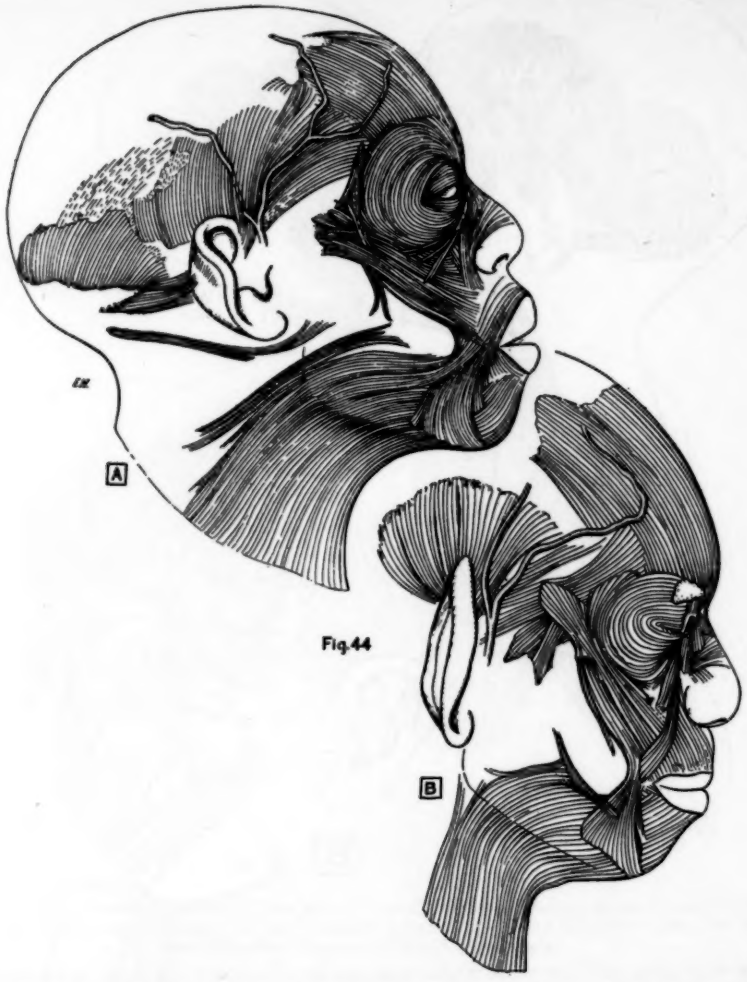

Fig. 44

FIG. 44. ADULT MALE NEGRO AND ADULT MALE AUSTRALIAN, WITH DISTINCT RACIAL CHARACTERISTICS

Fig. *a*. American Negro (Anatomy, Johns Hopkins University) showing the characteristic vast extension over practically the whole face of the coarsely bundled and powerfully developed mimetic musculature Most striking are the racial differences (as compared with the adult White of fig. 43) in the musculature of the mid-face, which shows a lack of differentiation. The *M. orbicularis oculi* of the Negro forms a huge powerful compact muscle disc, which far excels the corresponding muscle of the White. The relative width of the supraorbital and infraorbital portions of this muscle is just reversed in the two races, as corroborated through measurements of a large series of cases. In the Negro the width of the supraorbital portion exceeds that of the infraorbital portion. In the Negro, moreover, the marginal bundles of the *M. orbicularis oculi* are in broad primitive connection with the undifferentiated zygomaticus mass, while in the White, in a prevailing percentage of cases, the zygomaticus musculature is more independent of the *M. orbicularis oculi* and usually differentiated into distinct *Mm. zygomatici major et minor*, both with bony origin from the zygomatic arch. In the Negro the preauriculo-temporo-orbital musculature is well developed, while in the adult White, as already mentioned, this muscle complex is generally much reduced. In the Negro the musculature of the bulky lips and cheek walls (not shown in figure) is very massive (compare studies on "Negroes" by previous authors quoted in the literature list).

Fig. *b*. Australian aboriginal, modified after Burkitt and Lightoller. As to expansion and powerful development these grossly bundled muscles resemble greatly the negroid type; there are, however, characteristic Australian features present, such as the peculiar proportions of the *M. orbicularis oculi*, which differ from those of the Negro, as well as of the White. As Burkitt and Lightoller emphasize, the greatest width of the *M. orbicularis oculi* in the Australian does not lie at the center of the palpebral fissure, but considerably lateral to this. Most striking, moreover, is the unusual extension as far as the lip red of the "labial tractors," i.e. the zygomaticus muscle mass, *M. levator labii superioris proprius* and *M. quadratus labii inferioris* (compare further Burkitt and Lightoller, 1916/27).

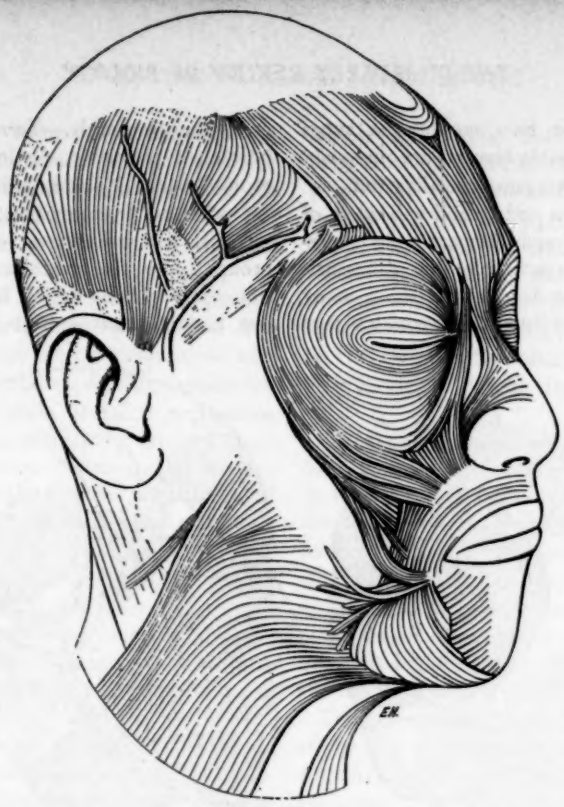

Fig. 45

FIG. 45. ADULT MALE POLYNESIAN (HAWAIIAN) (dissected by Thos. McP. Brown, Anatomy, Johns Hopkins University)

As in the Negro and Australian the mimetic musculature of this Hawaiian was found more extensive, more powerfully developed, and in the mid-face region less differentiated, when compared with the White. The musculature is compact but not coarsely bundled.

Most striking is the *M. orbicularis oculi*, which forms a powerful muscle disc around the eye. The supra-orbital and the infraorbital portion of this muscle measured vertically from the middle of the palpebral fissure are about of the same width, which equals the lateral extension of the muscle measured from the lateral angle of the eye slit; while the direct broad continuation of the lateral bundles of the *M. orbicularis* into the zygomaticus muscle mass adds considerably to the width of the muscle measured from the middle of the palpebral fissure along a line towards the zygomatic arch. The zygomatico-orbital muscle mass is in its upper part one with the *M. orbicularis oculi*, but in its continuation it splits up into several portions, which partly pass over the orbicularis oris-caninus muscle, partly dip under it, to be inserted into the upper lip; while a very strong, well defined deviating muscle portion joins the *M. risorius* close to the angle of the mouth. This latter portion together with the deep bundles of the zygomaticus muscle mass arises from the zygomatic arch. The insertion of several distinct muscle slips of the zygomaticus muscle mass into the upper lip and angle of the mouth is a noteworthy feature of the Hawaiian which was even more conspicuous on the left side. It indicates a decided trend towards further differentiation of this musculature.

Peculiar are the proportions of the *M. triangularis*, which arises from the mandible with a very broad basis, while its lateral, marginal bundles form a fan-shaped Risorius muscle.

Note also the vast expansion of the *M. auricularis anterior et superior*. While the orbito-auricular muscle bundles—representing the old phylogenetic connection between the *M. auricularis ant. et sup.* and the *M. frontalis*—are largely deteriorated (in contrast to conditions found in the Negro and Australian (compare figs. 44*a* and *b*), the upper part of the *M. auricularis ant. et sup.* is very well developed, and its bundles deviate upward to ascend parallel with the bundles of the *M. frontalis*. This is a progressive feature in the arrangement of the auriculo-temporo-frontal muscle complex in man. It is not infrequently seen in Whites, when this muscle complex persists in greater extent. It also occurs in other races (compare figs. 42, 44*a*, 46). In a similar extension it has been seen in the Javanese by Koster (1919).

Most unusual in this Hawaiian is the whorl in the upper median part of the *M. frontalis*. Such a formation has never been described, neither in the White or in any other race so far investigated. Future studies of additional Polynesians will prove whether the peculiar features seen in this Hawaiian are constant Polynesian characteristics.

ferences in the two monotreme types (*Echidna* and *Ornithorhynchus*) are obviously the result of divergent specialization.

In the various orders and suborders of the Marsupials and Placentals the superficial facialis musculature has differentiated to different degrees and along many and very distinct lines, a fact which makes the study of the superficial facialis musculature of high systematic value.

The Primates are naturally of special interest. Detailed comparative anatomical studies on the plan of the superficial facialis musculature in this order present important data on the relationship of the various groups of primates. As regards the facial musculature, outer ear, arrangement of facial tactile vibrissae, etc. the lemurs and *Tarsius* link with the other primitive placentals. *Tarsius* is specialized on a primitive, distinctly lemuroid ground plan. It shows unique features in the outer ear (ear cartilage, extrinsic and intrinsic ear musculature of the facialis group) and in the musculature of the eyelids,—mechanisms which in modern *Tarsius* have reached a high differentiation with corresponding evolution of the central nervous mechanism. These specializations are along an aberrant line, and not at all in the direction towards the higher primates. The findings on the superficial facialis musculature are in favor of the view that the platyrrhines may possibly have shed off from the *Tarsius* stock before the latter began to specialize along the line of modern *Tarsius*. These studies also suggest the possible derivation of the catar-

Fig. 46

FIG. 46. ADULT MALE CHINESE (from a joint study by the author and F. H. Langley, Anatomy, Johns Hopkins University)

The Chinese far excels the White as to the vast extension and powerful development of the coarsely bundled mimetic musculature. As in the Negro, Australian and Hawaiian the musculature of the mid-face region shows a lack of differentiation. Striking are the large dimensions of the *M. orbicularis oculi* which, however, in its proportions differs from the other racial types. It is the infraorbital portion which far exceeds the supraorbital portion. The vast extension of the platysma into the region of the face with almost vertically upward tending bundles in front of the ear may likewise be a racial characteristic of the Chinese. Note also peculiar features in the *M. auricularis posterior* and *M. occipitalis* (compare further Birkner, 1905; Kudo, 1919).

rhines from lower platyrrhine forms. They bring further data for the understanding of the genetic relationship of the members of the anthropoid stock, and of man's relation to the great anthropoid apes.

The gradual differentiation of the mimetic musculature in the primates in close correlation with the evolution of the corresponding central nervous mechanism led to the elaboration of facial expression, which in man ultimately attained marvelous perfection. There are evidences, however, that the mimetic musculature of man has not yet reached its final structural differentiation.

There exist noticeable racial differences in facial expression which are due to structural differences in the mimetic musculature, skin and subcutaneous tissue, but more so to differences in psychological reactions.

Experiments proved that we have *muscle sense in the mimetic musculature*, which is conducted together with muscle pressure sensibility by the *N. facialis*, though additional postural sensations may be indirectly appreciated through the sensory trigeminus.

With the unique evolution of the superficial facialis musculature in the mammals goes hand in hand the evolution of the central structures:

The motor part of the nucleus n. facialis is of corresponding dimensions.

In the Monotremes it is split up into two distinct nuclei, one dorsal and one ventral. The latter has shifted ventralward, but not into a definite ventral position. We have no definite knowledge in regard to the functional rôle of these two nuclei. There is, however, good reason to believe that not only the ventral but also part of the dorsal nucleus is motor.

In the Marsupials and Placentals only a very small part of the facial nucleus, mainly of visceral nature, retains the original dorsal position, while the other, purely motor part has shifted ventralward (presumably through neuro-biotactic influences) into a position close to the ventral surface of the brain stem. This motor nucleus is enormously increased in size, and subdivided according to the branching of the facial nerve which followed the differentiation of the facialis musculature.

The facialis musculature of the mammals has its representation in the *facial area of the cerebral motor cortex*. The facial area has frequently been subjected to investigation by many scientists in connection with general investigations on the motor cortex. However, the available data are very incomplete, in part contradictory and not at all correlated with the data from studies on the facialis musculature.

The motor facialis field is evidently one of the first which in the phylogeny of the mammals became definitely localized in the cerebral cortex. During the embryological development of marsupials and certain placentals however the facial area becomes responsive to electrical stimuli at a considerably later stage than the fore limb area, which in turn precedes the hind limb area. This is presumably due to a developmental adjustment, and not to a phylogenetic sequence.

In Monotremes (*Ornithorhynchus*) the readily responsive facial area in the motor cortex partly overlaps the fore limb area. Here hind limbs or tails have apparently no representation in the motor cortex.

In the Marsupials facial and fore limb areas still overlap to a certain extent. The hind limbs are imperfectly represented, and responses from this area are inconstant.

Within the orders of the Placentals there is a gradual evolution and fuller differentiation of the motor cortex: In the insectivores, bats and rodents the motor cortex

appears to have evolved little above the state found in the marsupials. The ungulates too seem not to have reached a higher differentiation. In the carnivores the various motor areas are well defined, and respond with more elaborate movements. Within the Primates, finally, the motor cortex, including the facial area, attains greatest completeness and highest differentiation in the anthropoid apes and man. Stimulation and ablation experiments in monkeys and apes, combined with physiological studies in man and clinical observations on patients offer an explanation for the well known fact that in central facial palsies the mimetic musculature of the upper part of the face is but little impaired. The explanation offered is that these mimetic muscles are bilaterally represented in the motor cortex. More detailed, special investigations on the facial area of the motor cortex in mammals should be undertaken with a broad knowledge of the peripheral facialis field.

The vast expansion of the motor facialis field in mammals is in striking contrast to the limited *sensory facialis field*, the cutaneous area of which is vestigial.

Together with the superficial facialis musculature, the *cutaneous field of the N. trigeminus* in mammals has attained a remarkably high development, and new functional connections were established between the two fields.

Under the domain of the sensory part of the *N. trigeminus* is the "oral sense" (tactile sense of the snout). In close correlation with the olfactory sense, the "oral sense" has highly evolved in mammals. This is reflected in the central nervous mechanism. As to the peripheral structures which serve the "oral sense" in mammals, the monotremes have developed along their own line, apart from the marsupials and placentals. In both *Echidna* and *Ornithorhynchus* the evolution of the sensory trigeminus culminates in the high sensitivity of the snout. *Ornithorhynchus* is in this regard unique.

The Monotremes, through their fundamentally different ground plan of the superficial facialis musculature, lack of tactile facial vibrissae and peculiar arrangement of the cutaneous branches of the *N. trigeminus*, just as in so many other points of their organization, are set aside from the rest of the mammals. One is tempted to conclude that the monotremes must have derived fully apart from the marsupials and placentals, from a different group of the theriodont reptiles.

The Marsupials and Placentals, on the other hand, show such striking resemblance in their ground plan of the superficial facialis musculature, in the restriction of the tactile surface of the snout to the rhinarium, in the possession of a tactile vibrissae apparatus actively moved by facialis muscles, in the arrangement of these facial vibrissae, and in the distribution of the cutaneous branches of the *N. trigeminus*, that these characteristics cannot possibly be explained as mere coincidences but must surely be considered the result of common ancestry.

The evolution of the sensory field of the *N. trigeminus* in the marsupials and placentals is closely linked with the acquisition of facial tactile vibrissae. The elaboration of this important head protecting and guiding mechanism was evidently an essential factor in the evolution of the marsupio-placentalian ground plan of the superficial facialis musculature. This in turn goes parallel with the differentiation of the facial area in the motor cortex. In Marsupials and in those placentals where the facial vibrissae are fully developed, vibrissae movements are an outstanding phenomenon in stimulation experiments on the facial area of the motor cortex.

The evolving tactile facial vibrissae

apparatus of the common ancestors of the marsupials and placentals, requiring sensory as well as motor representation in higher cortical centers, must have played an influential rôle in the early stages of evolution of the neopallium.

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THE "CONCEPT OF ORGANISM" AND THE RELATION BETWEEN EMBRYOLOGY AND GENETICS
PART II

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Polonius: Though this be madness, yet there is method in't.

IN 1925 H. S. Jennings (4) published a little book called *Prometheus*, in the Preface of which he stated that "The exposition of the relations of heredity and environment here given differs from that frequently set forth in the name of genetic science." He added, however, that nevertheless "it is presented as the outgrowth and fruit of the most orthodox genetics of the straitest sect of experimental Mendelism." An anonymous reviewer of this book in a well known biological journal wrote: "In this book the author ascribes greater importance to the environment in determining the nature of living things than most biologists do." That is all he said, beyond mentioning the fact that the book belonged to the "Today and To-morrow Series." Thus there appear to be three entities which have been sufficiently clearly discriminated by genetical science to have received distinct names: (i) one which is called "environment"; (ii) a second called "heredity;" and (iii) a third called "the nature of living things." Moreover, the third stands in the relation of "being determined by" to the first and second. We also learn that there is a *dispute* among biologists about the relative *importance* to be *ascribed* (by the biologists) to the first two entities in their relation to the third. Furthermore, it is clear that Jennings is in a minority among biologists in respect to the part *he* plays in this process of *ascribing* importance to these entities. It is evident too, that he is conscious of occupying what seems to be regarded as a somewhat unusual position, and so he is careful to explain that this is nevertheless "the outgrowth and fruit of the most orthodox genetics of the straitest sect of experimental Mendelism," although this explanation does not seem to have satisfied the reviewer. But there seems to be *something* in common between the majority and minority, and where they differ is in this process of *ascribing*.

The situation is not, however, so simple as this. In Germany there are eminent writers on genetics who are prepared to challenge, not merely the outgrowth and fruit, but even the root and branch of the straitest sect of experimental Mendelism, at least in the form in which it is presented by what they call the "*Morganschе Schule*." Finally, there is a small band of *franctireurs* called "Neo-Lamarckians," who keep up a perpetual sniping of all the various more widely held positions—muttering dark hints of superior rival theories of their own which they do not yet appear to have succeeded in formulating clearly. All this is very confusing to the onlooker—especially when he is urged to adopt *one* of the rival theories as a basis for sociological experiments. He should therefore be interested in an attempt to

discover what is common to *all* the contending "sects" and in finding a means of stating this in language which is independent of any one of the rival hypotheses.

There is another interesting passage in Jennings's Preface. He says: "The writer is not one of those who hold that inspired thinking may take the place of experiment in such matters." It may indeed be doubted whether anyone in the twentieth century has held that inspired thinking can take the place of experiment. The tendency is rather in the opposite direction—to suppose that experiment can take the place of inspired thinking. But surely one of these modes of procedure can no more take the place of the other than breathing can take the place of eating or vice versa. They are not two *alternative* procedures but two equally necessary and complementary ones. It is because they are complementary that it is necessary to know what each has to contribute, so that we do not fall into the error of expecting one to do what can only be demanded of the other. It may be that it is because this is not sufficiently understood that there is so much *ascribing*, and ascribing, being apparently a somewhat arbitrary and whimsical process, may be responsible for so much indecision and dispute over mere opinions in these matters.

Jennings adds that "The only conclusions at which we can rest are generalized statements of the observed facts. Such it is believed are here set forth." Now generalized statements of observed facts are inductive propositions—such as those expressing the Mendelian 3 to 1 ratio. There is little or no dispute about these. It is not here that ascribing enters, nor are these the conclusions at which Jennings and the others "rest" (if that is a suitable term for describing the present state of affairs). It is in regard to what can be *deduced* from such generalized assertions that most of the dispute arises. But there is another aspect of the situation which also occasions dispute, that, namely, regarding what *hypothetical assumptions* we can usefully *impose upon* the inductive data, in order to obtain the intellectual satisfaction afforded by a theoretical interpretation having the maximum generality coupled with the maximum adequacy. These two aspects are not clearly distinguished in the current theories. And, at least with regard to deduction, this seems to be a curious state of affairs, because if we have a set of inductive propositions then there will *also* be a set of propositions which can be validly deduced from them, if the ordinary laws of logic and certain a priori postulates are adopted. *If*, therefore, anyone admits the original generalizations, logical laws, and postulates, he is *compelled* also to admit the propositions which can be validly deduced from them. There is no choice in the matter at all, nor is there any place or need for ascribing. How is it then that there is so much dispute? It is customary to suppose that this is satisfactorily accounted for by uttering the one word "complexity"—even by those who assure us in the next breath that growth is a "simple physico-chemical process" (see Part I (14) p. 16). But it would be a pity to allow this word to become a cloak for slovenly thinking. So far as deduction is concerned the answer seems to be that insufficient attention has been paid to this side of biology, and the reason why there is so much ascribing rather than deducing is because the inductive generalizations are often couched in such vague metaphorical language. The very fact that such vagueness is so widely tolerated is a sign that no attempt is made at deduction. For as soon as you do attempt to use vague notions for deductive purposes their shortcomings at once reveal

themselves and you are driven to try to remove them. An inductive generalization will usually contain at least two terms and will assert some relation between them. If one or more of the terms or the relation are at all vague it will be impossible to use that generalization in a deductive argument with any hope of a clear and decisive result. The whole will be like a piece of badly made machinery in which defects are imperfectly compensated for by the use of padding and other makeshifts—corresponding to "ascribing."

If we analyse out all the different pursuits which go to the building up of a well developed science they will be found to include at least the following:

(1) "Empirical investigation" in the most restricted sense, i.e. the making and recording of actual particular observations, either under or not under experimental, or systematically altered, conditions.

(2) The extension of these observations with a view to discovering whether and how far they can be inductively generalized.

(3) The discovery of clear concepts to embody the inductive generalizations, and the construction of an unambiguous language in which to express them.

(4) The discernment of the type or types of logical order exemplified in a particular field of empirical investigation.

(5) The investigation of the logical properties of types of order as such, i.e. apart from their exemplifications (if any). This includes, but is not exhausted by, pure mathematics as ordinarily understood.

(6) The construction of theories embodying the data yielded by (1) and (2), systematized by the aid of (4), with or without the help of hypothetical entities (e.g. explanations of the "mechanical model" type in physics).

(7) The deductive development of (6) with the help of (5), leading to renewed investigation under (1) with a view to the "verification" of (6) and the checking of (2).

(8) The systematic analysis of the postulates and assumptions underlying (1), (2), and (6).

(9) The critical study of the ontological or "material" concepts employed in (6), e.g. space, time, thing, property, matter, etc.

(10) The study of the problems which present themselves when the question of the "truth" and "objectivity" of scientific knowledge is raised.

It will be seen that as we pass from (1) to (10) we pass from studies of restricted scope in which experiment plays the dominant rôle to others which are common to all the natural sciences and in which the chief requirement is "inspired thinking." Experiment can do two things: it can provide fresh data to think about, and it can decide between two rival hypotheses (reached by thinking) provided they are of the kind which *can* be decided by experiment, and some of our biological hypotheses are not of this nature.

The precise status of hypothetical entities conceived on the lines of perceptual models with properties "ascribed" to them appears to be very doubtful at the present day. The path of every branch of natural science is strewn with discarded entities of this kind, and there is no richer or more varied collection of them than that which has accumulated in the course of the history of embryology and genetics. The important point is that such entities are useless unless they enter as terms into an abstract logico-mathematical order-system which the empirical data of a given science exemplify. It is this feature which is usually lacking in the use of such entities in biology, in which they are invented *ad*

hoc and merely "do" what their inventor requires of them. Their value seems to be psychological rather than logical: they minister to our craving for the "tangible" and "concrete," but for all that they do not "wear" well. Only the facts and the order systems which they exemplify endure. Considerations based on the modern study of the relation between language and fact point in the same direction. Consequently there is a tendency at the present day to take a less crudely realistic attitude towards hypothetical entities than was formerly the case. Bertrand Russell (8) likens the present situation regarding our knowledge of nature to knowledge of a language which is confined to its grammar and syntax, with complete ignorance of the vocabulary, and what he says about "similarity" of relations is of special interest in this connection. On the other hand it would doubtless be a mistake not to take advantage of any help such hypothetical entities may afford, *so long as the logical links which bind them to what is observed* are not lost sight of, and so long as they are not conceived in such a way as to create obstacles to further progress. There is no occasion to set up the two methods in opposition to one another. In physics they have played into each other's hands in a beneficial manner, although there is sometimes an antagonism between "experimental" and "mathematical" physics. Russell himself writes in another place (9, p. 122):

> Physics, as such, should be satisfied when it has ascertained the equations according to which a process takes place, with just enough interpretation to know what experimental evidence confirms or confutes the equations. It is not necessary to the physicist to speculate as to the concrete character of the processes with which he deals, though hypotheses (false as well as true) on this subject may sometimes be a help to further valid generalizations.

On the other hand, on page 194 of the same work he says:

> It may be doubted whether science can retain its vitality if it is severed from its root in our animal habits; when set forth quite abstractly it loses plausibility. Induction, for example, is difficult to justify, and yet indispensable in science.

One of the chief difficulties of the modern world depends on the fact that the above mentioned ten studies are, to a very large extent, pursued by different workers independently of one another. And yet, at the same time, no one of them is ever pursued in complete intellectual isolation from ideas which are relevant to the others. No worker under (1), for example, will be entirely devoid of notions concerning the topics dealt with under the other headings. But each science begins with such notions borrowed from everyday life which it only gradually improves upon. These notions are frequently crude and misleading and, from lack of a deliberate critique of concepts and language which might be provided by the sciences under headings (8), (9) and (10), they may continue to obstruct the development of the budding empirical science. If genetics, for example, had started, so to speak, "from scratch" there would never have been so much misunderstanding and dispute. The way in which the language of daily life has kept older notions in countenance is well illustrated by the terms "heredity" and "inheritance." In their legal use these notions involve a three-termed relation as follows. There is first the testator, next the legacy or inheritance, and thirdly the legatee who receives the legacy. The relation of inheritance in this original sense is thus an irreducibly three-termed one. This is the *minimum*, but of course there may also be the family lawyer hovering in the background with his hand-bag containing the deeds. Now it is easy to see how this has influenced biological thought and how misleading it has been. Thus we have had the testator represented by the parents and the legatee

by the offspring, and then, since there is an intermediate term in the former relation it seems to have been felt that the same must be true in the biological one. Consequently we have had a third something, receiving various names, which is *what* is inherited. Even the family lawyer's hand-bag has been represented by the "bearers" or "carriers" of the something which is inherited, (in some cases even the lawyer himself "controlling" things!) But if we put aside such analogies and examine the biological situation we find that we do not have to deal with one which is at all comparable, and the use of the old terms is apt to perpetuate misunderstandings. For in biology the legacy and legatee seem to be one, not two, namely the zygote or fertilized ovum. Jennings remarks that "Possibly we should be better off with no such concept as heredity." But a detailed survey of the damage done by this vague, ill-defined, abstract substantive strongly suggests that "certainly" might here be substituted for "possibly." Jennings points out how "this habit of speech has led to conceiving heredity as something in itself, an entity, a 'force,' something that itself does things —an error that has induced clouds of misconception." But the same is true of many other abstract substantives in biology such as "phylogeny," "life," "function," "adaptation," and many others. It is customary to defend our current linguistic malpractices on the ground of "convenience." But if clouds of misconception are the price paid for convenience the whole purpose of language is frustrated.

The object of this article is to explore the groundwork of embryology and genetics in order to find out what is common to *all* rival theories, and with a view to discovering not what we can plausibly believe, but what we are compelled to infer. In order to do this we require to disclose (1) the well-established empirical generalizations which are commonly adopted; (2) the a priori postulates which are commonly adopted; and (3) the order-system within which inference in regard to these matters is possible. In Part I it was pointed out that what was there called "hierarchical order" provides such an order-system. This is now worked out in more detail and with greater precision in the hope that it will provide a means of conceiving more clearly some of the perplexities of developmental processes and their relation to genetical problems. We also require a language which is unambiguous, not drawn up in favor of one particular hypothesis, and "fool-proof" in the sense that it prevents one from making senseless assertions. The ideal would be to conduct our discussions in ideographic symbols. We are very far from reaching any of these ideals for a long time to come.

Another ground for the present disputes should be mentioned. At the time of Weismann genetical and embryological problems were not clearly distinguished. At the present day Neo-Lamarckians seem to be primarily interested in "adaptation." Evolution provides yet a fourth topic. These are all obviously related, but until the precise sphere of each is clearly and independently disentangled confusion is only perpetuated by prematurely mixing them up. The present article is only concerned with the first two topics. Part II will be wholly taken up by preliminary explanations and definitions of the notions involved, the inferences and applications being left to Part III.

II

It is unfortunately the case that in any attempt to clarify scientific concepts one is compelled sooner or later to devote earnest attention to questions which are

not biological at all, but which, as was mentioned above, are the concern of all branches of natural science. These questions can be postponed, but they cannot be indefinitely postponed. I will first briefly state what these questions are (or some of them), and then explain the attitude here to be adopted towards them from the biological standpoint. (1) The first is as follows: What is the relation between the entity which is placed on the stage of a microscope and is called a cell, and the entity which a cytologist actually *sees* when he looks through that microscope *at* the entity called a cell? Also, what is the relation between a cell, which is said to be perceived, and such an entity as a "gene," which is not supposed ever to be perceived? (2) The second question concerns the notions which are to be taken as ultimate in the description of nature. The answer to this question had at least the appearance of simplicity so long as it was possible to regard nature as consisting of a collection of small hard spheres just like billiard balls, but too small to be visible even under the microscope, and conceived as being incapable of change save in their spatio-temporal relations; and so long as it was possible to regard tables and chairs and rabbits as aggregates of such spheres, directly revealed in perception as regards shape and size, but with "mental additions" on the part of the observer as regards color, smell, etc. But now the hard spheres have given place to "centres from which radiations travel" and it is difficult to see any simple relation between the latter and "hard spheres." Moreover, it is now seen that the perceived size and shape must be treated on the same footing as the perceived color or smell. Consequently even the "macroscopic" billiard ball is no more perceived than the "microscopic" one in the *same* sense in which the colored shape is perceived. (3) Thirdly, it will be seen below that the present state of genetical theories is largely determined by the causal postulate, and not simply by "generalized statements of observed facts." This does not seem to be at all generally recognized. It is therefore necessary to make the working of this postulate perfectly clear, and to explain what is meant by calling it "a priori." A flood of light is thrown on many biological controversies as soon as the rôle of the a priori in them is made clear, and it is seen that often the dispute is about something which cannot be decisively settled by an appeal to experience.

(4) Finally, if we are to regard organisms as organized entities we require to know what we mean by "organization," in order to remove the defect in biological theory acknowledged by E. B. Wilson (13) when he says: "we are unable to define precisely the meaning of this vague term." In order to remove something of this vagueness I shall make use of some of the notions discovered by modern mathematical logicians, and it will therefore be necessary to give some explanation of these.

(1) Beginning, then, with the first question: it would obviously be out of place to discuss this topic here. All that one needs to do is to state as clearly as possible the attitude to be adopted and try to adhere to it consistently, but this is not intended to exclude other possible views. I shall call what a zoologist *sees* when he is said to be "looking at a rabbit" or "looking at a cell through a microscope" a "visual sense-pattern," and I shall assume that this is not "the rabbit" or "the cell," which is the subject of physiological propositions, as when we say "This rabbit is respiring," or "This cell is secreting mucin." The visual sense-pattern does not respire or secrete mucin. It is this particular rabbit, or this

particular cell, which respires or secretes. Consequently we cannot be said to "see" the rabbit in the same sense in which we certainly see the visual sense-pattern. On the other hand, the latter *may* sometimes be the subject of *anatomical* propositions, and I suspect that this has something to do with the separation of "structure" and "function." If this view is provisionally adopted we are next driven to consider how we are to conceive "the rabbit" (in the sense of a particular actual rabbit on a given occasion of perceiving), and since we are assuming that this and the sense-pattern are two different entities it will clearly be important to avoid transferring to the former properties which belong only to the latter. It will also be evident that "the rabbit" and such unperceived entities as molecules, atoms, genes, etc., are on the same footing in so far as none of them are perceived *in the same sense* in which the sense-patterns are perceived. If "the rabbit" is a system of molecules, and if these are systems of "centres from which radiations travel" then it is this system of "centres" which I am *perceiving* (in some sense) when I am *seeing* the visual sense-pattern *of* "the rabbit." This leads to the second question.

(2) Whenever we see the visual sense-pattern which is said to be the visual sense-pattern *of* a rabbit we perceive it in a place during a period of time, and *usually* this place is the place where "the rabbit" is said to *be* during that period of time. I shall give the name "place-date" to such a place-during-a-period-of-time, since every "place" is also a "date," although we can have a number of "places" with the same "date," and a number of "dates" with the same "place." I shall say that the visual sense-pattern is a *manifest pattern* (or apparent character) of the place-date. Now if we compare two manifest patterns and find them to be different we also usually assume (in accordance with the causal postulate) that the place-dates with which they are correlated are *also* different. I shall call this an *intrinsic* difference to distinguish it from the former or *manifest* difference. This does not enable us to say anything absolute about the two place-dates; we can only say that they are intrinsically *different*. But I shall make the further assumption (for biological cases) that when perception is non-delusive the place-date where-when the rabbit is said to be has also an *intrinsic* pattern. "The rabbit" *is* the place-date plus its intrinsic pattern. This is what Whitehead (12) means by an "event;" it indicates one at least of the senses in which he uses that term. The fundamental datum with which we deal in nature is, according to Whitehead, expressed in the word "process." Process presents two features which are fundamentally different but both essential to it. They are the irrevocable passage of process and the persistence of something in spite of it. Suppose you observe the rabbit during five minutes. Then the place-date which is the "situation" (in Whitehead's terminology) of the visual sense-pattern will be analysable into five place-dates of smaller temporal extent of one minute each. Each of these five place-dates is and passes irrevocably—the "place" as well as the "date!"—but "the rabbit" in one sense endures through them all. Thus "process" analyses into place-dates which pass and intrinsic patterns which endure. But intrinsic pattern in relation to living organisms cannot be thought of as endurance of undifferentiated sameness, as we realize when we consider development and physiological data generally. We can therefore defer any further explanation of these notions until they arise later in connexion with biological organization.

(3) But it will be desirable to leave the

further discussion of organization until the third question has been dealt with. In order to see clearly the working of the causal postulate the simplest plan will be to consider in some detail a simplified imaginary example. In any causal analysis we are always dealing with *differences*. In relation to embryological and genetical topics there are at least eight different *kinds* of differences involved which it will be necessary to distinguish carefully. Suppose we are given two sheets of white (*w*) paper *Aw* and *Bw* which are not *manifestly* different. They will be in an environment of some sort—e.g. air of a certain temperature, humidity, etc.,—call it *E*. We cannot say whether *A* and *B* are or are not *intrinsically* different. But suppose we cut a piece off *A* (call it *pAw*) and a piece off *B* (*pBw*). We place both *pAw* and *pBw* in a different environment *E'*, and find that *pAw* changes color to *pAx*, and *pBw* changes to a *different* color *pBy*. Then, applying the "causal formula" given in Part I, we should say:

$$D(pAw,\ pAx).C.D(E,\ E')$$

i.e. the manifest difference between *pA* on the first and second occasions is causally correlated with the difference of environment on the two occasions. Similar remarks apply to *pBw* and *pBy*. But whereas we had no manifest difference between *pA* and *pB* in *E*, we now do have a manifest difference between them in *E'*. Consequently we have, applying the formula:

$$D(pAx,pBy).C.D(pA,pB) \quad \text{and/ or} \quad D(E'pA,E'pB)$$

i.e. the manifest difference between *pA* and *pB* is causally correlated with either an intrinsic difference between *pA* and *pB*, or with a difference between their environments, or with both. But there is no environmental difference between them since they are both in *E'*. Hence *pA* is *intrinsically* different from *pB*. But this is only manifest in *E'*; what can we say about *pA* and *pB* in *E*? Are they *not* intrinsically different in *E* and only *become* intrinsically different in *E'*? It is here that the a priori nature of the causal postulate becomes apparent. If we assume that *pA* and *pB* are not intrinsically different in *E* and only become intrinsically different in *E'* we have nothing to correlate with the difference in their behavior in *E* and *E'*. The passage from *E* to *E'* "explains" the change from *pAw* to *pAx*, and from *pBw* to *pBy*, but it does not explain the difference between *pAx* and *pBy*. Consequently, *to preserve a symmetry of differences* we assume that *pA* is *throughout* intrinsically different from *pB*. This assumption can obviously never be proved or disproved by any empirical test, and is therefore in the strict sense of the term an a priori postulate. This same postulate underlies the following remark of D'Arcy Thompson (10):

> The appropriate and legitimate postulate of the physicist, in approaching the physical problem of the body is that with these physical phenomena no alien influence interferes. But the postulate, though it is certainly legitimate, and though it is the proper and necessary prelude to scientific inquiry, may some day be proven to be untrue. . . . .

But it seems plain that no such disproof could ever happen because we always assume what is necessary to *make* the postulate "true" (e.g. "potential energy"). It is the same postulate which leads Driesch to assume "entelechies" because he believes there are harmonious equipotential systems in which there is supposed to be nothing else to "make a difference" between one part and another to correlate with the observed difference in their behavior.

Returning to our example: suppose we now take two more pieces cut off from *A*,

call them $p'Aw$ and $p''Aw$. Place $p'Aw$ in E' and $p''Aw$ in yet another and different environment E''. Then, if the previous rule holds, $p'Aw$ will become $p'Ax$, and let us suppose that $p''Aw$ in E'' becomes $p''Az$. Then we have:

$$D(p'Ax, p''Az).C.D(p'A, p''A) \text{ and / or } D(E', E'')$$

If we assume that the spatial parts of A are uniform in their properties then $p'A$ will not differ from $p''A$, and hence the different behavior of $p'A$ and $p''A$ will be correlated with the difference between E' and E''. But since $p'Ax$ is manifestly different from $p''Az$ they will also be intrinsically different, but this will differ from the case of intrinsic difference between pA and pB in being known to be relationally or environmentally acquired, not an original intrinsic difference.

Suppose, finally, we take another piece ($p'Bw$) from B and, placing it in E'', observe a change to $p'Bz$. Then we shall have $p''Az$ and $p'Bz$ in E'', and consequently with respect to their behavior in E'' (as also in E) A and B are not different. But the causal postulate has already driven us to assume that A and B are intrinsically different, in spite of the fact that this is not manifested in E and E''. Because two entities are not manifestly different we cannot assume that they are not intrinsically different, but if they *are* manifestly different (under the same conditions of perception) this postulate drives us to assume that they are intrinsically different.

Now this whole procedure rests also on the assumption that whatever part we may cut off from A will have the same properties (in the three environments used) as any other part. Not only have we assumed this, but we have also assumed that A is uniform in its *temporal* parts, so that the properties of A do not change between the time of cutting off of pA and that of the cutting off of $p'A$ and $p''A$. It is in cases of this kind that we can use the notion of "stuff" or "material" or "chemical substance." The difficulties of biology rest very largely on the fact that neither of these assumptions can be made in regard to living organisms. A living organism is both spatially and temporally heterogeneous and both spatially and temporally organized, and, in so far as this is the case, in applying the notion of "stuff" or "chemical substance" we are abstracting from this heterogeneity and organization. In cases in which this organization is important this procedure will be fallacious if its abstractive nature is not remembered. But in other cases, in which only certain *parts* (later to be distinguished as 'constituents') are involved which are not organized in themselves no such abstraction will be involved. "Living matter" or "living substance" is a muddled notion because the concept of "stuff" or "substance" cannot be applied to a single whole organism, and the constituents to which it can be applied are not usually regarded as "living." This expression is therefore senseless, and its use only the outcome of a thoughtless habit.

We now require to distinguish between two kinds of intrinsic difference. There is first the kind of intrinsic difference we have between the place-dates round the ends of a magnet and the place-dates round the ends of a piece of wood. I shall call this a *relational* difference, since it is correlated with a difference between two other place-dates, namely the place-dates of the magnet and of the wood, and does not persist if the magnet is de-magnetized. But the difference between the magnet and the piece of wood I shall call a *specific* difference, since it does not appear to depend upon a *difference* between two other entities. The term "specific" will here be

used in this general sense, not in any special biological sense. It is sometimes forgotten that while causal analysis always involves comparison it does not tell us anything absolute about what is compared, but only about their *differences*. That is why we cannot speak of "inherited characters" and "acquired characters," but only of "intrinsic or genetic differences" and "environmental differences" (unless by these expressions are simply meant characters *usually* manifested at birth or hatching and those which may or may not be manifested later).

(4) In order to extend what was said in Part I about biological organization we shall need the following notions belonging to the logic of relations. If we use the symbol "xRy" for "x has the relation R to y" we can define the kinds of relations we require to discuss as follows:

(1) If when xRy we also have yRx, then R is said to be a *symmetrical* relation, e.g. if "x is spouse of y" then "y is spouse of x."

(2) If when xRy we cannot have yRx, then R is said to be an *asymmetrical* relation, e.g. if "x is father of y" then we cannot have "y is father of x."

(3) If xRy, then the relation in which y stands to x (which may or may not be R) is called the *converse* of R (here written conv. R).

(4) If we have x, y, z and R such that when xRy, and yRz we also have xRz, then R is said to be a *transitive* relation. But when xRz does not hold, R is called an *intransitive* relation. Thus "greater than" is transitive and "father of" is intransitive. Asymmetrical transitive relations are of immense importance in natural science because they are involved in the generation of series, and the whole possibility of deductive inference and of the application of pure mathematics depends upon them.

(5) If we have x, y, z and two relations R and S, such that "xRy and ySz" then the relation in which x stands to z is called the *relative product* of R and S (written $R|S$). Thus if "x is the mother of y" and "y is the father of z," then x stands to z in a relation which is the relative product of "mother of" and "father of," i.e. "paternal grandmother of." Relative products are of great importance in science, and the example given is an instance of the use of this notion in genetics.

(6) If "xRy and yRz" then x stands to z in a relation which is the relative product of R and R, and this relation is called the "square" of R (or R^2), and so on for other "powers" of R.

(7) A relation may be two-termed or *dyadic* (e.g. xRy), or three-termed or *triadic* (e.g. $R(x, y, z)$ "Uncle Tom leaves £50 to John") and so on for greater numbers of terms (polyadic or multiple relations).

(8) If "xRy" and there is no other term x' such that "$x'Ry$," and no other term y' such that "xRy'," then R is called a *one-one* relation. But if "xRy" and "xRy'" but no other term x' such that "$x'Ry$," then R is called *one-many*. And if "xRy" and "$x'Ry$" but there is no term y' such that "x (or x')Ry'" then R is *many-one*.

(9) If R is any relation the class of terms which stand in this relation to something or other is called the *domain* of R. And the class of terms to which something or other stands in relation R is called the *converse domain* of R. The *field* of R is the sum of the domain and converse domain of R (except in certain cases which need not be mentioned here).

(10) We shall also make use of the following definition of a "system" (see Chadwick (3)).

"The set of entities β is a system with respect to R" means: "If a set δ comprises some, but not all, of the elements of β, and if each entity comprised in δ is also an

element of β, then no matter what set δ may be, at least one entity comprised in δ has either R or the converse of R to some element of β which is not comprised in δ—R being a dyadic aliorelative relation." (An aliorelative relation is one in which a term cannot stand to itself, e.g. "greater than").

The above notions provide us with a means of giving a much more precise account of "hierarchical order" than was given in Part I. Figure 1 is a graphic symbol of a system of entities (represented by the dots) standing in hierarchical order.

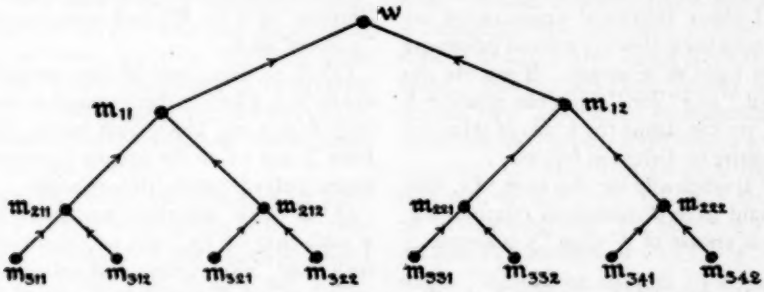

FIG. 1. GRAPHIC SYMBOL OF A SYSTEM OF ENTITIES IN HIERARCHICAL ORDER

The suffix numbers indicate (1) the level, (2) the assemblage within the level, to which a member belongs, and (3) the third number distinguishes one entity of an assemblage from the others. In the first level, where there is only one assemblage, the second suffix number is omitted. In a regular hierarchy in which the number of entities in a level is constant, if N is this number then the number of members of any level L_n is N^n, and each member of L_n stands to W in the relation $R_H{}^n$.

It is a system with respect to the dyadic, asymmetrical, intransitive, aliorelative relation symbolized in Part I by "R_H" and here represented in the figure by the barbed lines. It will be seen that this set of entities satisfies the above definition of a system. Also, if we let the symbol "$R_H{}^p$" stand for *any* power of R_H, and the symbol "$R_H{}^n$" for some one particular, but unspecified, power of R_H (throughout a given context), then it will be seen that the special feature of a system of entities in hierarchical order is that there is one unique entity in the system (W) to which every other entity of the system stands in a relation $R_H{}^p$, but which does not stand in such a relation to any other entity. We can now define a *level* (Part I, p. 8) as the class of members all of which stand to W in a relation which is the *same* power of R_H (i.e. $R_H{}^n$) in each case. And an *assemblage* will be the class of members all of which stand to a given member in the relation R_H. A given member is uniquely determined by the assemblage to which it belongs, and the class of members which stand in R_H to it. It will also be seen that although the relation R_H is intransitive, $R_H{}^p$ is transitive and asymmetrical, since if we take the three members m_{311}, m_{211}, m_{11} (in the figure) which are such that $(m_{311})\ R_H(m_{211})$ and $(m_{211})R_H(m_{11})$ then, although it is not the case that (m_{311})-$R_H(m_{11})$, it *is* true that $(m_{311})R_H{}^p(m_{11})$, and R_H is a value of $R_H{}^p$ (when $p = 1$). This transitive relation $R_H{}^p$ also determines a number of other classes. If we consider a given entity of the system, such as m_{12}, then a class of members is constituted by all those members which stand in $R_H{}^p$ to m_{12}. This class may be called the "posterity" of m_{12}, the term being used in this purely abstract sense. Similarly, there will be a precisely determined class

of members consisting of all those which stand in a relation to a given member, m_{343} say, which is the *converse* of $R_H{}^p$. This may be called the class of "ancestors" of m_{343}. These terms, as here defined, are borrowed from mathematical logic, but mathematical logicians have, of course, borrowed them from their particular use in reference to human pedigrees, and this use is simply a particular instance of the exemplification of their more general significance in the actual world. Whitehead and Russell (11) call this relation ($R_H{}^p$) the "relation of being related by some power of R." They denote it by R_{p_0} and say:

> in a series in which every term (except the first, if there is a first) has an immediate predecessor, and every term (except the last, if there is a last) has an immediate successor, if R is the relation of a term to its immediate successor, R_{p_0} is the relation of any earlier term to any later one.

This is the sense in which I use the symbol $R_H{}^p$.

We are now in a better position to consider organization, but instead of trying to define "organization" which is probably a hopeless undertaking, we can more profitably attempt to discover what we mean by a "single organized entity" or an "organized event." It is clearly not sufficient to say that by this we mean that the entity is a system in the above sense. If we pour out a bag of coins on the floor it is improbable that they will constitute a system with respect to a given geometrical relation. They will do this only if we arrange them deliberately in some geometrical pattern. But even so the collection as a whole will not constitute a single organized entity in the sense we require. It will not *be* a "whole" in the sense in which a living organism is a whole. What we have to do is to make clear the difference between, say, a mass of frog's spawn and a frog blastula. Both are "analysable into cells" but there is clearly a difference between them which we express by saying that the latter is a single whole organism and the former is not. The example of the coins shows that it is not sufficient to say that in the case of the blastula there is some relation between the cells with respect to which they constitute a system and that in the case of the mass of frog's spawn there is no such relation. This is evidently important but there is something more required. And one further requisite seems to be that this relation should be an *internal* relation in the sense that a given term (e.g. a cell) is different when it is in this relation to the other terms from what it is when it is not in this relation. The whole will then change in its properties when it is deprived of a part, and a part will have different properties when removed from the whole from what it has in its place as a part. The whole will have "Gestalt" properties in the sense of Köhler (6). The same principles can be illustrated from chemistry. If we consider a certain gas to be analysable into a finite number of monatomic molecules of two different kinds in equal numbers this will not constitute one whole entity, because there is no special relation between all the molecules, and if the walls of the containing vessel are removed the molecules will diffuse out into the surrounding gases. But if, say, a spark is passed and a chemical change occurs we can conceive this as a consequence of the atoms of the two kinds coming into some special relation in pairs. If we represent the two kinds by a and b and the special relation by R, then we shall have a number of couples aRb, and if R is an internal relation so that now the properties of a and b are different, then the whole collection of couples will exhibit properties which the gas did not previously exhibit. Each couple will be a

new molecule and we shall have a "compound." But we shall still have, not a single organized entity, but only a "quantity of stuff" or a "chemical substance," like the gas, in the sense explained above. But suppose some *further* change occurs and our compound proceeds to "crystallize." If *all* the couples now come into some relation S to one another which is internal and in which they do not stand to any other entity, then we shall have a single whole entity resulting from this process. Thus one way at least of conceiving a single organized entity is by regarding it as a system of entities with respect to some internal organizing relation, and as thus, as a whole, constituting an "intrinsic pattern." Whitehead (12) gives the following definition of "pattern"—a term much in vogue in biology nowadays:

> An object is a characteristic of an event. Such an object may be in fact a multiple relation between objects situated in various parts of the whole event. In this case the quality of the whole is the relationship between its parts, and the relation between the parts is the quality of the whole. The whole event being what it is, its parts have thereby certain defined relations; and the parts having all the relations which they do have, it follows that the whole event is what it is. The whole is explained by a full knowledge of the parts as situations of objects, and the parts by a full knowledge of the whole. Such an object is a pattern.

(The term "object" is here used in a very general sense for any "character" or "property" which endures amid the passing of "place-dates," see above.)

We now have to consider how we are to conceive change in an organized entity so that it may become specifically different from another organized entity. Let us simplify the situation by letting Figure 2a represent a simple organized entity with only four terms a, b, c and d standing in relations represented by the lines connecting them. This is merely a "graphic symbol" not necessarily a spatial diagram. It might equally well be written $(a, c, d)R(b)$ indicating that a, c, and d stand in a many-one relation R to b. Then, with our present ways of thinking, there appear to be three ways in which we can conceive a change in this intrinsic pattern. (1) In the first place (Fig. 2b) we may have a change in the *relations* in which the terms stand to one another. (2) Secondly (Fig. 2c) we may have a change in one or more of the terms themselves. (3) Or, finally, we may have a change in the number of the terms (Fig. 2d). If the relation in which the terms stand is an internal relation then changes of types (1) and perhaps (3) will bring with them changes of type (2). Which alternative (or a combination of two or more) is adopted in the interpretation of nature will of course depend on the requirements of the particular case. Chemistry furnishes examples of all three kinds. Now it will be noticed that if we

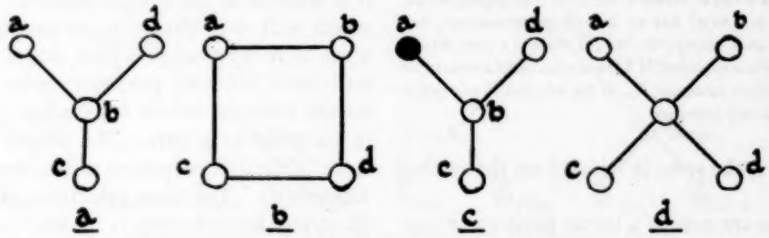

FIG. 2. GRAPHIC SYMBOLS REPRESENTING A SINGLE ORGANIZED ENTITY AND THE THREE TYPES OF CHANGE IT MAY UNDERGO

assume that a given term undergoes change of intrinsic pattern we have to suppose (under our present ways of thinking) that *it also* is analysable into terms in organizing relations, and then adopt one or more of the same three types of interpretation. And so *ad infinitum* or as long as necessary. If an entity is *unanalysable* we cannot interpret any change in it (if we adhere to our usual ways of thinking) except change in its spatio-temporal relations to other entities. Moreover, we cannot *say* anything about such an entity "in itself" but only about its relations to other entities, because there can be no assertion (and hence no knowledge properly so called) without at least two terms and a relation. Consequently we could say nothing about such an unanalysable entity except in so far as it is a term in some relation to something else. On the other hand we are compelled to assume that it has *some* property or character which distinguishes it from other entities, otherwise it would be a "bare portion of space-time" (see Part I, p. 17). Accordingly, if it were unanalysable this property could not be interpreted analytically in terms of differences between its parts. Thus our current ways of thinking lead *either* (1) to an indefinite regress of analysis, *or* (2) to ultimate entities which are either (a) capable of intrinsic change which cannot be interpreted analytically, or (b) incapable of change except change of spatio-temporal relations. But (quite apart from biology) there is "action at a distance" to be taken into consideration, and it is difficult to see how this is possible between entities which are incapable of change save of spatio-temporal relation (cf. relational difference), not to mention the recondite requirements of modern physics. Moreover colors, smells, sounds, feels, etc., (as well as biologists with their judgments and aspirations) have to be fitted into the scheme somewhere, and, although it is not the business of biology as such to fit them in, these considerations should warn us that our present ways of thinking are too simple to be adequate except within a certain range of application. It seems probable that we shall have to give up ultimate entities which are incapable of change save for change of spatio-temporal relations, and choose between an indefinite regress of analysis (as one physicist has suggested (1)), or admit entities which are capable of change which cannot be analytically interpreted. Whether the "concept of organism," when it is fully worked out, will provide a better scheme remains to be seen. In Part I. I suggested that we might contemplate the possibility of "determination" of an organic part "from without" as well as "from within," by "synthesis" as well as by "analysis." In other words that, in an organism, the properties of a part depend on the part *of which* it is a part, as well as on the parts into which it is analysable. It is presumably something of this sort that people have in mind when they speak of "organic determination." But it is difficult to bring it into relation with the usual analytical scheme. The difficulty rests on the difficulty of conceiving the relation between a "place-date" and any enduring character it may have on *any* scheme. We are fogged by notions about "things" and their "properties" which we take over from everyday life. There, it suffices to think of things and their properties as standing in a two-termed relation, but scientific investigation shows that we have to do with many entities in multiple relations of great complexity. "Properties" are "shared" between many place-dates, rather than "possessed" by the one of which the property is "predicated." Predication, as Whitehead says, is a "muddled notion." Accordingly we require to

conceive the properties of an organic part or component (see below) as a kind of "surface" or "intersection" (metaphorically speaking) between the components into which it is analysable and the component of which it is a component. We thus have to get out of the habit of regarding only the supposed "ultimate" components as "really real." Otherwise it is quite arbitrary to stop at cells, or genes, or molecules, or even atoms. We require to do justice to each level in the hierarchy of levels.

When an organized entity is divided we appear to have three theoretical possibilities. It may disintegrate into a number of temporally uniform stable elements, or it may be divided into two or more organized entities which are either intrinsically different from one another (as when a molecule is divided, according to chemical theory), or not intrinsically different from one another or from the original. In the latter case (which appears to occur in the division of some cells, and in *all* cells in so far as the products of division *are* cells) I shall speak of the *spatial repetition* of the original pattern. We have temporal repetition of an intrinsic pattern when it is repeated in every temporal part of an event, i.e. when we have a string of non-simultaneous place-dates all with the same pattern. But with spatial repetition of a pattern we have two simultaneous exemplifications of this pattern in two different events.

From the point of view of the intrinsic difference or non-difference between the three entities concerned when one organized entity divides there are five theoretical possibilities. These are represented graphically in Figure 3, in which *a* represents the entity divided, and *b* and *c* represent the products of its division. The continuous lines represent difference and the dotted ones represent non-difference. This scheme will be useful in connexion with types of cell-division.

There are two ways in which we can conceive two organized entities coming into relation to form one organized entity. Either they may do so in such a way that they constitute two terms or components in a new whole, which would then have a different organization from that of either of the two originals. Or, we might have a process of "fusion" in which the two entities lose their singleness and form one pattern of the same type as that of the originals, a possibility which seems to be realized in syngamy.

FIG. 3

III

After these preliminaries, which are not special to the biological sciences, we can turn to their applications in biology. Our first task is suggested in the following passages: A. B. Kempe wrote (5):

> So far as the processes of exact thought are concerned, the properties of any subject-matter depend solely on the fact that it possesses "form"—i.e. that it consists of a number of entities, certain individuals, pairs, triads, &c., of which are exactly like each other in all their relations, and certain not; these like and

unlike individuals, pairs, triads, &c., being distributed through the whole system of entities in a definite way.

And J. Royce wrote (7):

The prominence of quantitative concepts in our present physical theories is nothing that we can regard as absolutely necessary. There may be, in future, physical sciences that will be highly theoretical, and that will not use quantitative concepts as their principal ones. Yet it is certain that they will use some exact conceptual order-system.

Similarly, C. D. Broad says (2):

All reasoning depends entirely on the logical or formal properties of the objects reasoned about.

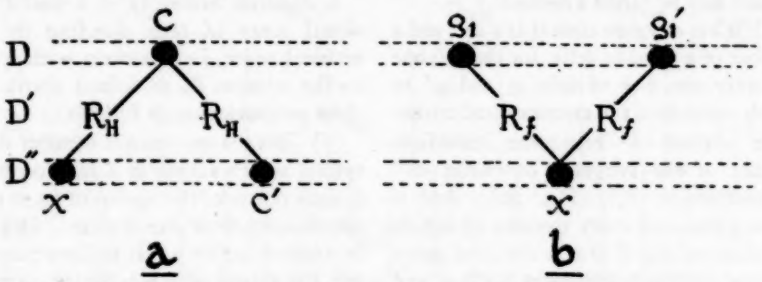

FIG. 4. GRAPHIC SYMBOLS OF (A) A DIVISION TRIAD, AND (B) A FUSION TRIAD
The intervals between the broken lines represent three durations and their temporal relations, but not their relative lengths.

We therefore require to discover, if possible, what are the formal properties of the entities involved in biological reasoning, and the properties of the order-systems into which they enter, and in virtue of which inference in regard to them is possible. Beginning with cells, some of their most important formal properties are as follows:

(1) If x is a cell, x is neither analysable into entities which are cells, nor is it a part of an entity which is a cell.

(2) If x is a cell, it occupies a determinate position in a system of cells (called in Part I a "division hierarchy") which is a system with respect to a relation (symbolized by R_H) to be explained immediately, and every cell belongs either to the domain or to the converse domain of this relation, or to both. Cells which belong *only* to the converse domain of this relation are called zygotes. We will consider non-zygotes first.

(3) If x is a cell which is not a zygote then there is one and only one cell c to which x stands in the asymmetrical and intransitive relation of "being an immediate division-product of" (symbolized by R_H), and, if attention is confined to binary division, there is one and only one cell c' which *also* stands in this relation to c, (Fig. 4a). Thus every cell which is not a zygote is a member of such a triad of cells, the members of which stand in perfectly determinate relations to one another. Their time relations are such that if D is a duration every moment of which intersects the organized event which is c, then there will be another duration D'' every moment of which intersects x and c', and there will be a third duration D' every moment of which intersects some phase of the division of c. And these durations (if they all belong to the same family of durations) will be serially ordered, so that D is earlier than D', and D' is earlier than D''. And since c is itself a cell it also (if it is not a zygote) will conform to the above properties and will stand

in the relation R_H to one and only one cell belonging to a duration which is earlier than the one to which it itself belongs. If we continue in this way we obtain a chain of such "division triads," and every cell will belong to such a chain and will belong either (a) to both the domain and the converse domain of R_H, or (b) only to the domain of R_H, e.g. a cell which does not divide, or (c) only to the converse domain of R_H, in which case it will be a zygote. (A cell which belongs to ***both*** the domain ***and*** the converse domain of R_H may be called a ***link***, and one which belongs ***only*** to the domain ***or*** converse domain may be called a ***terminus***.)

(4) If x is a zygote then it is a cell and a member of a triad of cells, for there is one and only one ***pair*** of cells g_1 and g_1' to which x stands in the asymmetrical intransitive relation of "being the immediate product of the syngamy or fusion of" (symbolized by R_f), (Fig. 4b). And if D'' is a duration every moment of which intersects x, and if D is a duration every moment of which intersects both g_1 and g_1', then there will be another duration D' every moment of which intersects some phase of the process of the fusion of g_1 and g_1'. And these durations will be serially ordered so that D is earlier than D', and D' is earlier than D''. Thus with respect to time this "fusion triad" may be described as "inverted" as contrasted with the division triad.

Division Hierarchies. Unfortunately these properties are not sufficient to determine a division hierarchy because with reference to a given cell we cannot say whether it will or will not divide. Some cells do not divide. Consequently we cannot include dividing among the essential properties of organized events having the intrinsic pattern of a cell and without which an entity would not ***be*** a cell. A cell which did not belong to either a division or a fusion triad would be, from the standpoint of our present knowledge, a "miracle," but a cell which did not divide would not be regarded as anything miraculous. Accordingly we can only say that ***if*** a cell, which is not a component of an organism (see below), divides, and ***if*** each of the resulting cells divides, and ***if*** this process continues, then we shall have a division hierarchy (symbolized by dW) generated, (Fig. 5), (only binary division will be considered in this paper, but the following remarks, with appropriate modifications, will also apply to multiple division).

A division hierarchy is a four-dimensional array of cells standing in hierarchical order, i.e. a system with respect to the relation R_H as defined above. Its chief properties are as follows:

(1) There is one unique member of the system which stands in a relation which is some power of the ***converse*** of R_H to every other member of the system. This will be symbolized by o. It endures throughout a duration which is earlier than any other duration containing members of the system. If o is a member of a fusion triad it is a zygote. If the two other members of this triad (g_1 and g_1'), which are called gametes, belong to different division hierarchies we have "cross-fertilization;" if they belong to the same division hierarchy we have "self-fertilization." Since g_1 and g_1' belong to a duration which is earlier than that to which o belongs, they cannot belong to the division hierarchy of which o is the first member. If o is not a zygote it will belong to a division triad, and will stand in R_H to some cell which is a component of some spatial hierarchy (see below) of which o is not a component, and we have "parthenogenesis" (in Metazoa).

(2) It will be noted that o corresponds to the entity W of the abstract description of a system of entities in hierarchical order.

(3) When o divides and a division hierarchy is generated from it there are two possibilities: (i) the members remain in organizing relations to constitute components of one whole organized entity and a spatial hierarchy (see below) is generated (in Metazoa), or (ii) the members do not remain in organizing relations, but each constitutes one organism (in Protozoa).

(4) If x and y are any two cells in a division hierarchy then either (i) $xR_H^p y$, or (ii) $yR_H^p x$, or (iii) there is some third cell z to which they both stand in a relation which is R_H^p (but not necessarily the same power in each case), and which is such that it does not stand in conv. R_H^p to any cell to which x and y *also* stand in R_H^p; z may then be called the *last common ancestor* of x and y.

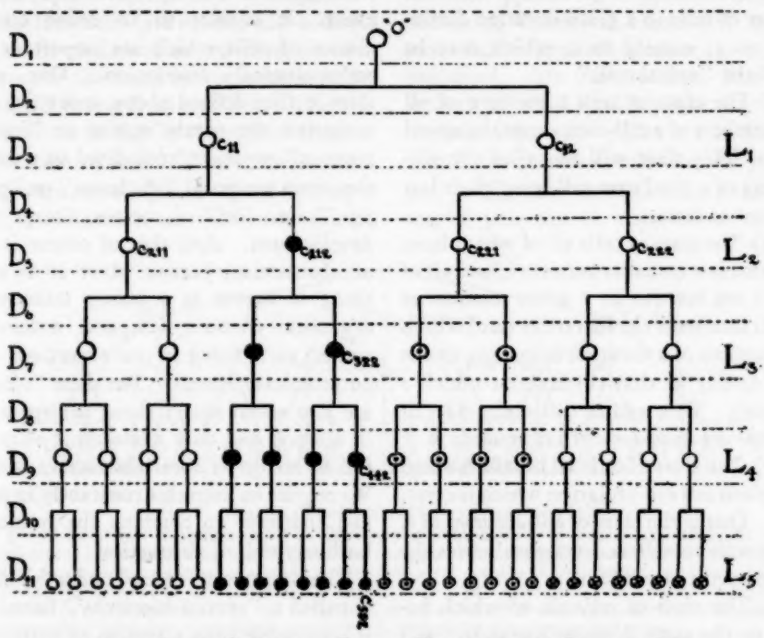

FIG. 5. GRAPHIC SYMBOL OF A DIVISION HIERARCHY UP TO DURATION D_{11}

The intervals between the broken lines represent durations and their temporal order, but not their relative lengths. A given cell is to be conceived as enduring throughout the duration represented by the interval between two adjacent lines between which it is drawn. Thus the cell c_{211} endures from the beginning to the end of D_4. This figure represents an "ideal" (i.e. logically simplest) hierarchy, in which division occurs simultaneously in every member of each level. In nature this is usually only the case in the earlier levels. The cells represented by the blackened circles constitute a "cell-cone" of which c_{212} is the "apical cell." The cells marked with a dot constitute the cell-posterity of cell c_{221}. The cells marked with a cross constitute the contemporary descendants of cell c_{212} in duration D_{11}. The series of cells c_{1221}, c_{122}, c_{212}, c_{11} and o, constitute the cell-ancestors of cell c_{1222}.

(5) A division hierarchy is analysable into certain classes of cells which are precisely determined by powers of the relation R_H. Some of these classes are important embryologically and genetically, and it is useful to have names for them. They might all be important if we had the requisite empirical data to make use of

them in a given case. The most important of them are as follows:

(i) The class of cells consisting of a given cell c (which is other than o) and all the cells of the hierarchy which stand in R_H^p to c. This will be called a "cell-cone" because as we go back in time the number of cells in a given duration diminishes to 1, namely to c, which may be called the "apical cell."

(ii) The class of cells consisting of all the members of a cell-cone *except* the apical cell c. This class will be called the *cell-posterity* of c, the latter cell being their last common ancestor.

(iii) The class of cells all of which have the same last common ancestor c, and all of which are termini at a given moment m which intersects the hierarchy (and which is a moment of a duration belonging to the same family as that throughout which o extends). This will be called the class of *contemporary descendants* of c at moment m.

(iv) The class of cells all of which stand to a given cell c in a relation which is conv. R_H^p. This is the class of *cell-ancestors* of c. These cells constitute a temporal series the earliest term of which is o.

(v) The class of cells all of which belong to the same division hierarchy; and consists of *all* the cells of that hierarchy existing at a given moment m (which is a moment of a duration belonging to the same family as that throughout which o extends). This (in Metazoa) will be the "purely momentary" organism of anatomy at the moment m. This brings us to the second exemplification of hierarchical order in the biological realm, namely to "spatial hierarchies."

IV

Spatial Hierarchies. In considering the division hierarchy we are being very abstract. We are dealing only with those aspects of the biological world which flow from the properties of cells as entities constituting the fields of the relations R_H and R_f. But this is a useful abstraction. In the metazoa (with which we are here primarily concerned) it enables us to refer to the whole four-dimensional organism throughout its history, i.e. as one "long" event. It enables us to define certain classes of cells which are important for embryological description. One such class is that defined above under (v) and comprises the purely spatial or "instantaneous" organism considered in abstraction from temporal "thickness" or "passage," i.e. "at" a certain "stage" of development. And this of course is also an abstraction, because there is no such thing in nature as a purely momentary organism without temporal extension, and no such thing in our experience as a durationless moment. But these "ideals" are also useful abstractions, indispensable in science, and only misleading when we fail to recognize their abstractive nature. We require to keep this constantly in mind and endeavor to combine the results of both methods of abstraction.

The class of cells defined under (v) above is called a "spatial hierarchy" because it is analysable into a system of entities in hierarchical order. In this case the entity W is represented by the whole spatial organism, and the other entities of the system are represented by its spatial "parts." The relation R_H is the relation between, say, a given cell and the cellular part of which it is a part, or between a given cellular part and the whole (in certain cases) of which it is a part, and so on, (Fig. 6). But the term "part" is very ambiguous, and it is important, from the standpoint of biological organization, to discriminate clearly between some of its meanings. In the first place we may mean a "bare part"—a "bare portion of space-time"—considered in abstraction

from any character or intrinsic pattern it may have. But the two kinds of parts we require to distinguish from the biological standpoint are what I shall call "components" and "constituents." A *component* of an organism will be defined as a spatial part which is an *assemblage* of the spatial hierarchy (see below) and is therefore to be conceived as including no components of the hierarchy other than those to which it stands in a relation which is the converse of R_H^p (in the spatial sense or application of R_H). Thus a nucleus is a component, a cell (except o) is a component, and the entire central nervous system

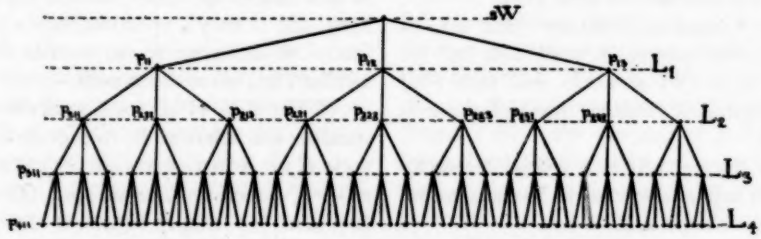

FIG. 6. GRAPHIC SYMBOL OF A SPATIAL HIERARCHY (sW)

In spatial hierarchies there is of course no fixed number of members in an assemblage, hence the number depicted here (3) is of no general significance. Also the nature of the components of a given level will differ according to taxonomic position or according to the temporal position in the division hierarchy. Thus in Protozoa L_1 would represent cell-components of the first order. In a gastrula L_1 would represent the primary germ-layers, L_2 would represent cells, and L_3 the level of cell-components of the first order. In later stages L_1 would represent cellular components of the first order, L_2 those of the second order, and so on.

of a vertebrate would be a component. Thus we have (i) cell-components, (ii) components which *are* single cells, and (iii) cellular components. If a cellular component has components which are cellular it is a compound cellular component. Thus the cells of a given spatial hierarchy can, theoretically, be regarded (i) from the point of view of their distribution among cellular components, and (ii) from the point of view of their distribution among cell-cones. A *constituent*, on the other hand, is either any arbitrary part taken without regard to the hierarchical order, e.g. a beef-steak, or it is a spatial part of an organism which lies outside the hierarchical order, i.e. does not stand in conv. R_H to components, e.g. cartilage or bone matrix, connective tissue fibres, blood-plasma, yolk and secretion granules. It is in relation to constituents of this kind as opposed to components that the notion of "chemical substance" can be most safely applied because, as already explained, this notion does not take account of the hierarchical or any other organization, but applies to entities in which the spatial distribution of properties or character is uniform, so that one spatial part can be regarded as a "fair sample" of the whole, or "some" is representative of "all."

We can now distinguish between *temporal* parts or "slices" of a four-dimensional division hierarchy (in Metazoa) and *spatial* parts. A temporal slice is always a whole spatial hierarchy, whereas a spatial part is either a component or a constituent, or, it may be, a "bare" part, of a spatial hierarchy. But of course a *purely* spatial part is just as much an abstraction as is a purely spatial organism. Where there is any risk of ambiguity it will be desirable (for the present) to use the symbol $R_H(s)$ for the hierarchical rela-

tion in spatial hierarchies, and $R_H(d)$ for the corresponding relation in reference to division hierarchies. A spatial hierarchy will be symbolized by "*sW*". The following are some of its chief properties.

(1) Since a spatial hierarchy is defined as a class of cells it may be a class with only one member. This is the case during the earliest duration of the division hierarchy, when there is only one cell, namely *o*. In all other durations the spatial hierarchy contains more than one cell, in Metazoa. But in Protozoa cells do not belong to the domain of $R_H(s)$, since the level of organization in a spatial hierarchy does not rise above that of a cell.

(2) A spatial hierarchy (and also a cellular component) is analysable into (i) *n* cells, of (ii) *m* kinds, and into (iii) the organizing relations in which the cells stand.

(3) If every cell in a spatial hierarchy stands to it in the relation R_H there are no cellular components.

(4) If a cellular component stands to the whole spatial hierarchy in the relation R_H it is a cellular component of the first order. If it stands to *sW* in a relation R_H^2 it is a cellular component of the second order, and the component of which it is a component (and to which it stands in R_H) will be a compound cellular component.

(5) Similarly, if a cell-component stands to a given cell in R_H it is a cell-component of the first order, if in R_H^2 it is a cell-component of the second order, and so on.

(6) If we describe a compound cellular component merely in terms of its cells we are abstracting from any special properties they may exhibit as members of one of its second-order components.

(7) Just as in the division hierarchy, so here also, the powers of the relation R_H (in this case $R_H(s)$) determine certain classes (in this case classes of components). These are as follows:

(i) The class of all parts which stand in R_H^p to *sW*, i.e. the class of all components ("living parts") of an organism.

(ii) The class of components all of which stand to a given *sW* in a relation which, in each case, is the *same* power of R_H, i.e. a level.

(iii) The class of components all of which stand to a given component in a relation R_H^p, i.e. the class of components of a component, or the (spatial) "posterity" of a component.

(iv) The class of components all of which stand to some component *p*, which is a component of *sW*, in a relation which in each case is the same power of R_H (i.e. R_H^n), and is thus a selection from a level limited with respect to the relation of its members to a given component.

(v) The class of all components which stand in the relation R_H to a given component, i.e. a particular case of (iv) when $n = 1$, hence an assemblage. (Classes (iv) and (v) simply represent different degrees of analysis of a given component).

(vi) The class of all components which stand to a given component *p* in a relation conv. R_H^p, i.e. the (spatial) "ancestry" of a component. For example, a given chromosome will belong to one and only one cell, and this will belong to one and only one cellular component of the *n*th order (if such there be in the hierarchy), and so on.

(vii) The class of all parts which do *not* stand in conv. R_H to components. This is the class of constituents which are not analysable into components, thus excluding beef-steaks but not excluding cartilage matrix. Such constituents "lie outside" the spatial hierarchy, but not "outside" the organism. Thus an organism possessing such constituents cannot, as a "whole" be a system *simply* with respect to the relation $R_H(s)$. From this point of view a molecule, or an atom, or an electron

(whatever interpretation may be given to those terms) will, if it belongs to the (spatial) "posterity" of a given component, be just as much "alive" as a cell, and one which does not belong to the posterity of a component will be "dead." There is no sense whatever in asking whether this is "true." It is merely a *partial* statement of a possible meaning of the term "alive," as applied to a part. It gives expression to one aspect of living organisms which the "concept of organism" embraces, to the fact, namely, that the whole requires its components in order to "be alive," and the parts require the whole in order to make their particular contribution to it in virtue of which it is "alive." In other words, the term "living" applies not to the components as such but to the components in their organizing relations in virtue of which they display their special *relational* properties (cf. Part I, p. 15). *If* these relations are internal relations this must be so, but whether, in a particular case, this is so can only be discovered by experiment. It is in view of such considerations that I shall restrict the term "environment" to the environment of a whole organism, or of a component isolated from the whole. If this term is used indiscriminately for the environment of a whole and for the specific organizing relations in which a component stands when it *is* a component, then the important difference between the two situations is obscured, and, in cases where this difference cannot safely be ignored, avoidable difficulties will be created.

V

Genetic Hierarchies. We now reach the third exemplification of hierarchical order in the biological realm (Fig. 7). The symbol "*dW*" has been used for a division hierarchy, and "*o*" for its first unique member. Where, in an argument, we require to distinguish different division hierarchies we can put a numerical suffix after the symbol *dW*, and a corresponding suffix after the "*o*" from which it is generated. The symbols "g_1" and "g_1'" have been used for the two gametes from the fusion of which a given "*o*" results. Where it is necessary to distinguish a zygote by a suffix number the corresponding pair of gametes can be distinguished by placing in brackets with a corresponding suffix number after them. Instead of saying "the zygote o_1 results from the union of the gametes g_1 and g_1'," we can express this more concisely by "$(o_1)R_f(g_1, g_1')_1$" (the comma being read "and"). We can use the symbols g_1, g_2, g_3, etc., for different gametes of the same (male) division hierarchy; and the symbols g_1', g_2', g_3' etc., for different gametes of another (female) *dW*. For any cell of a division hierarchy other than an *o*-cell or *g*-cell the symbol "*c*" is used, with or without a numerical suffix as required. Instead of saying "the cells c_2 and c_3 both result from the division of c_1," we can express this more concisely by putting "$(c_2, c_3)R_H(c_1)$". All these notions have perfectly clear meanings and occur so frequently in embryological and genetical discussions that it is profitable to have symbols for them which allow the successive steps in an argument to be stated in a compact, uniform and precise form, as will be shown in Part III. A genetic hierarchy can be described as follows:

(1) If o_1 is a zygote (Fig. 7), then there is one and only one pair of gametes $(g_1, g_1')_1$ such that $(o_1)R_f(g_1, g_1')_1$.

(2) And there will be one and only one zygote o_{11} such that $(g_1)R_H{}^p(o_{11})$, and there will be one and only one zygote o_{12} such that $(g_1')R_H{}^p(o_{12})$.

(3) Consequently, there is one and only one *pair of zygotes* (o_{11}, o_{12}) to each member of which o_1 stands in a relation which is

the *relative product* of R_f and $R_H{}^p(d)$. This relation has the same formal properties as the *converse* of the relation R_H, and we can therefore call it conv. $R_H(g)$, since it is the converse of the R_H relation for genetic hierarchies.

(4) Now since o_{11} and o_{12} are zygotes they will also stand in similar relations to other zygotes. There will be a pair of zygotes (o_{211} and o_{212}) to which o_{11} stands in conv. $R_H(g)$, and a pair of zygotes (o_{221} and o_{222}) to which o_{12} stands in conv. $R_H(g)$; *and so on.*

(5) Consequently a given zygote o_1 determines a system of zygotes which is a system with respect to the asymmetrical, intransitive relation $R_H(g)$, i.e. the relation in which o_{11} and o_{12} stand to o_1. And since this is an instance of the hierarchical relation this system will constitute a hierarchy of which o_1 represents the entity "W," o_{11} and o_{12} represent the two members of the highest level, o_{211}, o_{212}, o_{221}, and o_{222} represent the four members of the level next below the first, and so on. The four zygotes last mentioned will stand to o_1 in a relation which is the square of $R_H(g)$.

(6) But it will be seen that this system differs from the other hierarchies we have considered in being only a *selection* from a wider system which has the character not of a hierarchy but of a *network* of intersecting hierarchies. For o_1 may not be the *only* zygote standing in conv. $R_H(g)$ to o_{12} and o_{11}, and similarly o_{11} may not be the only zygote standing in conv. $R_H(g)$ to o_{211} and o_{212}. Consequently we can only speak of a hierarchy *with respect to a given zygote.* We can express this by saying that a genetic hierarchy (as here defined) is a selection from the field of the relation $R_H{}^p(g)$ obtained by taking a given member of the field (such as the zygote o_1) together with all the members which stand in $R_H{}^p(g)$ to it. Thus two or more gene-

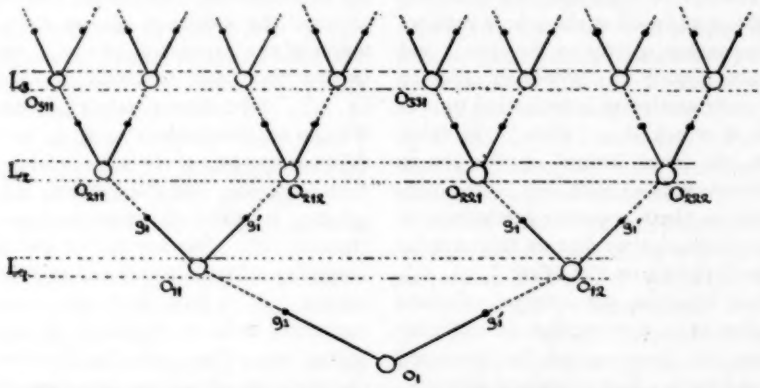

FIG. 7. GRAPHIC SYMBOL OF A GENETIC HIERARCHY WITH RESPECT TO THE ZYGOTE o_1

The relation $R_H(g)$ is a relation between zygotes, but this relation is the relative product of two relations, namely the converse of RH^p (between a given zygote and a certain gamete g_1, belonging to its cell-posterity), indicated by the broken lines, and the converse of R_f (between g_1 and the zygote into the constitution of which it enters), indicated by the continuous lines. Consequently, although the gametes are not terms in the relation $RH(g)$ and are not members of the hierarchy, they are shown in the figure as the intermediate terms in the relative product. Durations are not indicated, but it is evident that the members of a given level L_n (although they may belong to different durations) will extend through durations all of which are earlier than durations extended over by members of levels higher than L_n, and later than durations extended over by members of levels lower than L_n.

tic hierarchies may be identical except for the entity corresponding to "W," and the class of zygotes which can be substituted for the zygote corresponding to "W," while leaving the rest of the hierarchy unchanged, will consist of "brother" or "sister" zygotes. This class gives *one* meaning of the term "generation." We can define a generation as a class of zygotes all of which stand in conv. $R_H(g)$ to a given pair of zygotes, and the term can then be extended to the division hierarchies generated from them. This is the sense in which an "F_1 generation" is a generation, but not necessarily that in which an "F_2 generation" is a generation.

(7) Since a genetic hierarchy is a selection from a network there are other ways in which the selection might be made. We might treat a given pair of parental zygotes as representing "W," and their offspring as the "first level," and so on (as was mentioned in Part I), but the above method is simpler and brings out clearly the analogy with the other exemplifications of hierarchical order. The genetic hierarchy is "inverted" with respect to time as contrasted with the division hierarchy.

(8) Another complication is introduced by the fact that the same member may occur twice in a given hierarchy. For example, o_{331} may be identical with o_{311}, these being merely different symbols for the same zygote. In this case o_{211} and o_{221} (if they were both "male") would be "half-brother" zygotes. ("Maleness" of course has different senses, and a zygote is not "male" in the same sense in which an adult slice of its division hierarchy may be "male").

(9) In cases where "self-fertilization" is the rule, so that g_1 and g_1' both stand in $R_H{}^p(d)$ to the *same* zygote we should obtain a different system of zygotes in which the zygote-ancestors of a given zygote would constitute a *series*. The system would be a hierarchy which would not be inverted with respect to time as contrasted with the division hierarchy. The same graphic symbol which serves for the latter would then serve for the former, except that the number of members in an assemblage would not necessarily be limited to 2, (as it is when division is binary). In what follows the term "genetic hierarchy" will refer to systems of the first or "inverted" type.

(10) It will be seen that powers of the relation $R_H(g)$ determine certain classes of zygotes which are exactly analogous to the classes determined by powers of R_H in the other hierarchies. These are given in the table below.

(11) The above description of a genetic hierarchy (gW) will, like the description of a division hierarchy (dW), apply both to Metazoa and to Protozoa in which syngamy occurs.

VI

It would be a great mistake to expect too much of "hierarchical order," or to suppose that everything can be got out of it. But it does appear to be *a* type of order underlying embryology and genetics, and one which determines the lines along which biological inference moves in relation to these topics. Incidentally the above instances of its application illustrate some points of scientific methodology which were mentioned in Part I (p. 5). These preparatory clarifications (which do not profess to be by any means exhaustive) have occupied the whole of Part II. But the proof of the pudding is in the eating, and in Part III it should be possible to state clearly the relations between the various sciences which are here involved, and to develop deductively the consequences of well established generalizations in embryology and genetics without

reference to any particular hypothesis, and without too much recourse to "ascribing," in order to discover what is common ground between existing rival speculations, and how far their differences are traceable to avoidable obscurities.

Three exemplifications of hierarchical order in biology. Classes determined by powers of R_H

IN THE ABSTRACT	IN dW	IN sW	IN gW
(1) Members standing in R_H^p to W.	Cell-posterity of an o-cell.	Spatial "posterity" of a whole.	Zygote-ancestors of a zygote.
(2) Members standing in R_H^n to W (where $n > 1$).	Cells of level n.	Components constituting level n.	Zygotes of level n.
(3) Members standing in R_H to W.	First two cleavage cells (Metazoa).	Cellular components of the 1st order ("organ system").	Parental zygotes.
(4) Class (1) + W.	dW.	sW.	gW.
(5) Members standing in conv. R_H to W.	Null.	Null.	Null.
(6) Members standing in R_H^p to a given member m.	Cell-posterity of a cell c.	Components of a component p.	Zygote-ancestors of a zygote o.
(7) Members standing in R_H^n to a given member m (where $n > 1$).	Sub-class of a level limited by relation of its cells to a given cell c.	Components of level n which are components of a given component p.	Parental, or grand-parental, or . . . - parental, etc., zygotes of zygote o.
(8) Members standing in R_H to a given member m (assemblage).	Immediate division products of a cell c.	Components belonging to level $n - 1$) of a component belonging to level n.	Parental zygotes of a given zygote o.
(9) Class (6) + m.	A "cell-cone."	A component.	A gW with respect to zygote o which stands in $R_H(\xi)$ to some other zygote.
(10) Members standing in conv. R_H^p to a given member m.	Cell-ancestors of a given cell c.	Spatial "ancestors" of a component p.	Descendants of a zygote o limited to a given gW.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

L'ÉVOLUTION EN BIOLOGIE. *Fondation "Pour la Science." Centre International de Synthèse. Première Semaine Internationale de Synthèse. Premier Fascicule.*

Exposés by Maurice Caullery, Émile Guyénot, and P. Rivet. *La Renaissance du Livre* $5\frac{1}{2}$ x 8; xv + 84 (paper) *Paris*

The *Centre International de Synthèse* (*Fondation "Pour la Science"*) appears to be the equivalent of an extremely high-brow American Open Forum. This little volume is its first publication. Two distinguished biologists and an equally distinguished anthropologist lectured pleasantly and shrewdly on different aspects of evolution and here are the lectures and the discussion of them from the floor. Caullery starts by reviewing, in a masterly way, the development and present condition of our ideas about evolution, and ends, as so acute a thinker is bound to, on an agnostic note as to the mechanism of evolution, with a pessimistic overtone as to the improbability of any speedy solution of the problem. Guyénot next reviews the bearing of modern genetic research, particularly that on mutations and chromosomes, on the evolution problem. Finally Rivet sums up, with the precise, critical realism of French science at its best, what is known of the evolution of man. Again the conclusion reached falls far short of ruddy optimism. The truth is, and Rivet says so, that the fossil man branch and the fossil ape branch of the evolutionary tree both plunge separately down into the remote past, and there is not the faintest trace of factual evidence to tell us at what epoch they were joined together in a common trunk, if ever. Rivet ends by saying that while Karl Vogt maintained that he would rather be a perfected ape than a fallen angel, we now know that man is neither of these. This book should not be allowed to fall into the hands of a Fundamentalist. At the same time, however, the publishers of the various series of dollar tracts, about science and other things present and future, are missing a good bet if they do not publish a translation of this little book.

EMBRYOLOGY AND EVOLUTION.
By G. R. de Beer. *Oxford University Press*
$2.00 4¾ x 7½; viii + 116 *New York*

This little book is the result of a "simmering revolt" on the part of the author when he came to the realization that the "theory of recapitulation was not all that it claimed to be." In presenting his arguments against this theory and for a return to the earlier concepts of von Baer the writer states his case with simplicity and directness. An excellent book to put in the hands of advanced students.

GENETICS

THE HORSE OF THE DESERT.
By William Robinson Brown (with an Introduction by Major General James G. Harbord and Henry Fairfield Osborn).
The Derrydale Press
Regular edition $27.50 *New York*
De luxe edition $100.00
9½ x 12½; xxviii + 218

Sad experience teaches a reviewer to look with a bilious eye upon luxuriously produced volumes in quarto written by rich men about their hobbies. They are apt to be such dilute and poisonous pap that even the condiments of beautiful paper, typography and illustrations cannot make them digestible. This volume on the Arabian horse is a rare and notable exception to this class of books to which apparently and superficially it seems to belong. It is a meaty and salty treatise. The author is now the leading breeder of the Arabian horse in America, and has gone into the vitals of his hobby with unusual depth and thoroughness. Every library of genetics should most certainly have this volume on its shelves.

The book opens with an account of a trip to Arabia to purchase breeding stock. A Ford sedan furnished motive power. In a fairly wide acquaintance with the travel literature about Arabia the reviewer has never come upon so completely debunked an account of that interesting country and its inhabitants as this appears to him to be—and he is not forgetting Doughty or T. E. Lawrence. It is quite simply and therefore charmingly written, and plainly is not only truthful but true. One's only regret is that there is not more of it.

The book then goes on to a useful account of the origin and history of the Arabian horse, its anatomical, physical and mental qualities, and its blood lines in Arabia, all showing real, thorough scholarship, and a rich knowledge of Arabian lore. Other breeds of horses are then discussed in their relations to the Arabian. A chapter gives shrewd and detailed advice about purchasing breeding stock in Arabia. The final chapter discusses the usefulness of the Arabian, especially for cavalry purposes. A long bibliography and a detailed index complete a notable book, which is beautifully printed and superbly illustrated.

ÉTUDES SUR LES MALADIES FAMILIALES NERVEUSES ET DYSTROPHIQUES.
By O. Crouzon. *Masson et Cie*
55 francs *Paris*
6¼ x 9⅛; viii + 385 (paper)

This is an interesting volume, which will be useful to all students of human biology for reference, on the nervous and dystrophic diseases recognized to be familial in their incidence. Seventeen chapters are devoted to the familial nervous diseases, and fifteen to the familial dystrophic. The discussion throughout is essentially descriptive in character,

rather than philosophical. The author catalogues and describes the known facts with admirable precision and compactness. The author obviously knows the literature of his subject thoroughly. It is a pity that he did not increase the usefulness of his book by including a systematic and comprehensive bibliography.

CONTRIBUTIONS TO THE GENETICS OF DROSOPHILA SIMULANS AND DROSOPHILA MELANOGASTER. *Carnegie Institution of Washington Publication No. 399.*

By A. H. Sturtevant, C. B. Bridges, T. H. Morgan, L. V. Morgan and Ju Chi Li. *Carnegie Institution of*

$4.00 (paper) *Washington, D. C.*
$5.00 (cloth)

6¾ x 10; 296

Eight papers in this volume record hitherto unpublished data on the genetics of *Drosophila* by Morgan and his associates. The results reported may be said, in the main, to clarify and amplify points already known from the author's earlier work, and to "complete the record."

VERSUCH EINER THEORIE DER GENKOPPELUNG. *Bibliotheca Genetica Band XV.*

By K. v. Körösy. *Gebrüder Borntraeger*
40 marks *Leipzig*

7⅛ x 10⅛; xii + 272 (paper)

A detailed discussion, primarily mathematical, of the theory of linkage and of chromosomal mechanics in relation to genetics generally, covering similar ground to that of the earlier work of Haldane and Jennings but proceeding to wider generalizations. The volume is dedicated to the memory of Jacques Loeb. Its observational data are drawn from the work of Morgan and his colleagues.

LA VARIATION ET L'ÉVOLUTION. *Tome I. La Variation.*

By E. Guyénot. *Gaston Doin et Cie*
32 francs *Paris*

4½ x 7; xxviii + 457 (paper)

A well-written semi-popular discussion of the results of modern genetics, especially concerning itself with the mutations of *Drosophila*. There is a bibliography of 36 pages and an index.

GENERAL BIOLOGY

EDUCATIONAL BIOLOGY.

By W. L. Eikenberry and R. A. Waldron. *Ginn and Co.*

$2.48 5⅛ x 7⅝; viii + 549 *Boston*

EDUCATIONAL BIOLOGY. *The Contributions of Biology to Education. A Textbook for Teachers' Colleges and University Schools and Colleges of Education.*

By John C. Johnson. *The Macmillan Co.*

$3.00 5¼ x 7¾; xx + 360 *New York*

Most colleges, universities, and normal schools now require of students completing two and four year teacher training courses some type of instruction in Biology as a basis for the study of the principles of education, educational psychology, educational sociology, nature study, elementary science, health education, etc. This instruction is also intended to be vocational, that is, of practical value in the schoolroom as an aid in the solution of problems of behavior. At many institutions this "core" subject has received the name of "educational biology," and it is hoped to develop it to the prominence that educational sociology and educational psychology have received in the education curriculum. Now so much of the time of the prospective teachers is devoted to methods courses, practice teaching, etc., that the content of most basis courses suffers. Thus educational biology

at the present time, despite the protests of many who teach it, is a one semester course. The administrative difficulties referred to prevent the giving of laboratory work in most cases, hence it is recommended that generous provision be made for demonstration and visualization.

As biologists, we are glad for the recognition of this function which biology may be made to serve, but we fear that the program is too ambitious under the conditions prescribed, especially since it appears to be the common experience of those who have taught both liberal arts and education students, as well as the supreme mentors in "education" themselves, that the latter group of students does not measure up mentally to the former group. Indeed, it is said on good authority that at least one investigation, whose publication was suppressed, showed that liberal arts trained teachers obtained quite as good results as those with specific training in methods from teachers' colleges in a certain state, a fact which might have had some influence on the appropriations granted the rapidly developing teachers' college system there. In last analysis, then, this latest fad course in biology would seem to raise anew, and in a time when the supply of teachers seems to be exceeding the demand, the old question of genuine standards among our brethren in "education" or the problem of methods vs. content, as expressed in the popular conception that a knowledge of teaching methods is an adequate substitute for wide knowledge of subject matter. The hopeful sign, however, is that the teachers' colleges, lately of a secondary level, show signs of early becoming vocational liberal arts colleges.

As regards the books listed, the first, so far as presenting an intellectual challenge is concerned, is scarcely better, if any, than some of the really good secondary texts on the market. Its emphasis is on physiology with a debatable minimum of anatomical detail. Only loose thinking will group a horseshoe crab in an illustration with a common crab under the title "crabs" together with the qualifying statement that it is not closely related to the common crab. More perniciously false is the statement that insulin cannot be administered by mouth, as every physician can testify. And this is biological *science*, and humanization of it with a vengeance!

The second, despite an occasional minor discrepancy, is of a decidedly high scholastic tone. The greater part of it is composed of materials which we would associate with courses in evolution, heredity, and eugenics, with really excellent teaching applications interspersed. Thus it is essentially the latter third of a liberal arts course in biology but without the antecedent preparation. While we appreciate the author's courage in thus assaulting the soft science situation prevalent in the teachers' colleges, we wonder how he can do justice to such materials with the background of the students, for the authors of the first text, teachers present or past in the same system, apologize for the nonchallenging character of their book by the statement that investigations indicate about one-half of those enrolled in teachers training courses have had no previous training in Biology!

After all, why not a good course in General Biology instead of this stuff, with teaching application, suggestions, and above all, humanisms as it goes along?

A CONTRIBUTION TO THE KNOWLEDGE OF FLORIDA ODONATA. *University of Florida Publication, Biological Science Series, Vol. I, No. 1.*

By C. Francis Byers. *University Bookstore*
$1.00 *Gainesville, Florida*

5⅝ x 9⅛; 327 (paper)

This stout volume contributes the first of a special series of contributions from the Department of Biology of the University of Florida. It is an excellent account of the dragon flies of the state, treating first the taxonomy and then the ecology. One hundred and nineteen species are listed, and 114 described, the other five listed being dubious. Seventeen species were reared from nymphal instar stages to adults, seven of these furnishing new life histories. To the general biologist the ecological section will be the most interesting, with its accounts of habits and habitats. A penetrating discussion of distribution and migration leads to the conclusion that temperature is the most important single factor affecting the distribution of Odonata in Florida, acting as a barrier to their migration.

PUBLICATIONS OF THE UNIVERSITY OF OKLAHOMA BIOLOGICAL SURVEY, *Vol. I, Nos. 1, 2, 3.* Containing following articles: *Tentative Program of the Survey*, by A. Richards; *Notes on Oklahoma Fishes*, and *Oklahoma and Arkansas Fishes*, by Carl L. Hubbs and A. I. Ortenburger.

University of Oklahoma Press
$1.00 *Norman*

6 x 9¼; 112 + 13 plates (paper)

An extensive survey of the State of Oklahoma should yield very interesting results. The area, besides being a meeting place for fauna and flora from the north and the south and from the east and the west, contains regions of high and low rainfall, salt plains, high plateaus, extensive forested areas and grass lands. While a certain amount of field work has already been done by independent workers it is now planned to organize the work. An outline of the program is presented in this bulletin together with two papers on fishes of the state and neighboring regions.

PRAKTIKUM DER GEWEBEPFLEGE ODER EXPLANTATION BESONDERS DER GEWEBEZÜCHTUNG.

By Rhoda Erdmann. *Julius Springer*
14.80 marks *Berlin*

6 x 9½; viii + 148 (paper)

The second edition, not greatly enlarged, but considerably rewritten and improved, of a useful treatise on the technique of tissue culture, with brief laboratory directions for a course in the subject.

HOLIDAY MEADOW.

By Edith M. Patch. *The Macmillan Co.*
$2.00 7⅜ x 8; 165 *New York*

This, a book for young children, is a charming and accurate introduction to animal and plant life as found in any meadow one might come upon during a short stroll. The illustrations are usually not well reproduced.

PRESSON BIOLOGY TEST. *Test 1: Plant Biology. Test 2: Animal Biology. By John M. Presson, under the direction of LeRoy A. King.* *World Book Co.*
Yonkers, N. Y.

Test 1 and Test 2 sold separately in packages of 25, $1.20 per package

6¼ x 10; 52 (paper)

HUMAN BIOLOGY

HUMAN HISTORY.
By G. Elliot Smith.
W. W. Norton and Co., Inc.
$5.00 5¾ x 8½; xviii + 472 *New York*

The purpose of this book "is to search for the deep motives that have shaped Man's career, and to call attention to the vital factors in human thought and behaviour which have been ignored by most writers." The author is an authority on the comparative morphology of man and an eminent teacher of anatomy. This book will arouse much controversy among biologists and humanists. Whether it will bring about a cooperation of the biologists and the humanists towards a better understanding of human thought and action remains to be seen.

The chief aim of such a study should be, according to the author,

> study of the actions of the organism as a whole, the behaviour of living men and women in all its puzzling manifestations. Moreover it should include something more than behaviour in the sense of such actions as can be observed and recorded. The thoughts and feelings that provide the motives for men's behaviour are the things that matter most.

A great deal of credit for the distinctive character of civilization is given to the embalmer. The art of mummification developed out of the great urge to find a way to "prolong the existence of the body so that it might be reanimated as a living being." This created "not only many of the essential arts and crafts (architecture, stone and wood-working, sculpture and painting, the drama, dancing and music) that represent the scaffolding of civilisation, but also the deepest aspirations of the human spirit, the motives which have influenced the thoughts and actions of countless millions of human beings throughout the whole history of civilization." But many centuries before the era of mummification man was "building up the fabric of civilisation under the influence of doctrines based upon his ideas of the functions of the heart and blood, the breath and moisture, the placenta and the hypothetical 'life-substance.' " Primitive man he believes to have been and still to be (as he is found in remote places today) "decent, generous and peaceful." However, early civilization, once under way, was concerned with building up a system whereby individuals were more or less subjected to the tyranny of a State System. A new era in the progress of civilization was ushered in in the sixth century B.C. when the Ionians broke down the heavy shackles which this system imposed on the great mass of people and men and women became free to "think and act without restraint." Since that time "human history has been a conflict between the rationalism of Hellas and the superstition of Egypt." To ancient Egypt he gives the credit of laying the foundation of civilization.

The book contains many illustrations, a brief bibliography and an index.

BULLETIN DER SCHWEIZERISCHEN GESELLSCHAFT FÜR ANTHROPOLOGIE UND ETHNOLOGIE. *1929/30. 6. Jahrgang.*
By the Société Suisse d'Anthropologie et d'Ethnologie. *Büchler und Co.*
6⅛ x 9; 32 (paper) *Bern*

THE IMMIGRANT WOMAN AND HER JOB. *Bulletin of the Women's Bureau, No. 74.*
By Caroline Manning.
U. S. Government Printing Office
30 cents *Washington*
5¾ x 9⅛; ix + 179 (paper)

A survey under the auspices of the

Woman's Bureau of the Department of Labor, to ascertain in what manner the immigrant woman is fitting into American industrial life. Over 2000 women were interviewed. Two regions were studied. Philadelphia with its large clothing and textile industries, besides numerous lesser trades, offers a wide variety of occupations for the immigrant woman. In the Lehigh River Valley, 50 miles to the north of Philadelphia, where originally were only steel and cement works, large cigar factories and silk mills have grown up since 1905, giving employment to great numbers of women. Austria and Hungary have furnished the larger part of the workers in the Lehigh Valley, while in Philadelphia Russians predominate.

The report is divided into three sections. The first "deals with the problems of the women in industrial employment, the second with the much smaller group occupied more casually in industrial home work, and the third with the women attending the beginners' English classes in the Philadelphia Public Evening Schools." A very adequate summary of the results is given in the last three pages of the report. In an appendix are given the schedule forms.

LA POPOLAZIONE DI TRIESTE (1875–1928).
By P. Luzzatto Fegiz.
Istituto Statistico-Economico
9½ x 13½; 106 *Trieste*

THE MONEY VALUE OF A MAN.
By Louis I. Dublin and Alfred J. Lotka.
The Ronald Press Co.
$5.00 5⅝ x 8⅜; xv + 264 *New York*

The authors have applied Farr's method to modern American life tables and wage scales in order to estimate the present worth of the gross and net future earnings of men of different ages and income classes. The book should be of great use in questions of compensation for injury or death. It is interesting to note the conclusion that the earning capacity of the population has increased rather than decreased as a result of the advance in the mean age of our population.

YOURSELF, INC. *The Story of the Human Body.*
By Adolph Elwyn. *Brentano's*
$3.50 5¾ x 8⅝; iv + 320 *New York*

The great popular success of Dr. Logan Clendenning's "The Human Body" seems to have stimulated the production of a host of similar treatises. The present volume is a clear, accurate and unsensational account for the general reader of the simpler elements of human anatomy, physiology, and hygiene. The book is a sound rather than brilliant performance. It is rather more sparingly illustrated than is usual in popular biological books. Its real field of usefulness seems to us likely to be found as a text for high school and small college classes in hygiene, rather than as entertainment for the general reader.

ANTARCTIC ADVENTURE AND RESEARCH.
By Griffith Taylor. *D. Appleton and Co.*
$2.00 5 x 7⅞; xi + 245 *New York*

Professor Taylor, himself geologist in Scott's last expedition, gives in this book a history of Antarctic exploration and a description of the geography, climate and resources of the Antarctic regions. Although it inevitably lacks some of the picturesque detail that enlivens narratives

of individual expeditions, it will serve as an admirable background. The book contains both bibliography and index.

YOUTH AND CRIME. *A Study of the Prevalence and Treatment of Delinquency Among Boys Over Juvenile-Court Age in Chicago. United States Department of Labor, Children's Bureau Publication No. 196.*
By Dorothy Williams Burke.
U. S. Government Printing Office
35 cents *Washington*
5¾ x 9⅛; v + 205 (paper)

This is a study of the prevalence and treatment of delinquency among boys over juvenile-court age (17 to 20 years of age) in Chicago. Statistics covering the years 1915 to 1925 collected by the police department, the jail and the municipal court furnish the basis of the report. The first two sections deal with "General findings and recommendations" and "Methods of dealing with boy offenders in Chicago." The third section gives an analysis of a selected group of cases (972) dealt with by the boy's court branch of the municipal court, while the fourth and last gives a detailed study of 82 boys handled by the same court. In Appendix A is discussed the extent to which cases studied represent the entire group and in Appendix B the exclusion of certain cases.

OUTLINE OF JEWISH KNOWLEDGE, *being a History of the Jewish People and an Anthology of Jewish Literature from the Earliest Times to the Present; including a Brief Account of the History of Civilization of the Nations with Whom the Jews Have Come into Contact, and an Exposition of the Present-day Status and Problems of the Jewries of the World. In Twelve Volumes. Vol. I. Founding of the Nation. From the Earliest Times to the Death of Saul.*
By Israel Goldberg and Samson Benderly.
Bureau of Jewish Education
$2.00 5½ x 8½; xxviii + 382 *New York*
10% discount for 10–20 copies
20% discount for 20–50 copies

This is the first of a series of volumes intended to make Jewish history and literature better known to the younger generation of Jews. The authors follow the traditional account rather closely, with much the same slurring over of the more blood-thirsty aspects of the religion of the early Hebrews as is customary in Christian accounts of the Old Testament.

PROCEEDINGS OF THE THIRD RACE BETTERMENT CONFERENCE, JANUARY 2–6, 1928. *Under the Auspices of the Race Betterment Foundation, Battle Creek, Michigan.*
Race Betterment Foundation
$5.00 (cloth) *Battle Creek*
$2.00 (paper)
6 x 9; xxx + 748

A collection of papers read by various authors, some of whom were men of science, on numerous aspects of eugenics, as well as other forms of the uplift, at a series of meetings at the Battle Creek Sanitarium, under the auspices of the Race Betterment Foundation, of which the president is stated to be Dr. John Harvey Kellogg.

THE BANTU TRIBES OF SOUTH AFRICA. *Reproductions of Photographic Studies. Vol. II, Section I, Plates I–XXVI. The Suto-Chuana Tribes. Sub-Group I, The Bechuana. With Introductory Articles on The Suto-Chuana Tribes and the Bechuana,*

by G. P. Lestrade, and Descriptive Notes on the Plates.
By A. M. Duggan-Cronin.
Deighton, Bell and Co., Ltd.
21 shillings *Cambridge, Eng.*
8⅛ x 11½; 23 + 26 plates (paper)

Section 1 of Volume II of this interesting and valuable anthropological study of the Bantu tribes contains an introductory chapter, a section on the Bechuana, and twenty-six excellent photographic plates with descriptive notes. A review of Section 1, Volume I has been given in an earlier number of this journal.

SPECIAL REPORT ON CONTRIBUTORY CAUSES OF DEATH. 1926. *Canada. Dominion Bureau of Statistics, Demography Branch.*
F. A. Acland
Free 6½ x 9¾; 150 (paper) *Ottawa*

SPECIAL REPORT ON ORDER OF BIRTH OF CHILDREN BORN IN 1925. *Canada. Dominion Bureau of Statistics, Demography Branch.*
F. A. Acland
Free 6½ x 9¾; 49 (paper) *Ottawa*

The data on order of birth are tabulated by age of mother and occupation of father. The sizes of family for different occupations show much the same tendency as in other countries, the wives, aged 40–44 years, of professional workers having borne 4.67 children, while the wives in the same age-group of fishermen had borne 8.83 and those of coal miners 8.87 children.

UNDER HEAD-HUNTERS' EYES.
By A. C. Bowers. *The Judson Press*
$2.00 net 5 x 7⅞; 248 *Philadelphia*

The author of this book, having been a missionary for more than twenty-five years in Assam and Bengal, writes of the ideals and outlook of these people as they have been revolutionized by the impact of Christianity. Naturally he has many interesting things to say, but his point of view is swayed by his desire to show that "the idealism of Christ is already bearing fruit in giving healing and peace to many."

THE IMMIGRATION WORK OF THE DEPARTMENT OF STATE AND ITS CONSULAR OFFICERS. *Department of State Publication No. 22.*
U. S. Government Printing Office
10 cents *Washington*
5¾ x 9⅛; iii + 49 (paper)

A statistical account of the work of the Department of State in administering the Immigration Act.

CARE OF AGED PERSONS IN THE UNITED STATES. *Bulletin of the United States Bureau of Labor Statistics No. 489.*
U. S. Government Printing Office
70 cents *Washington*
5¾ x 9⅛; vi + 305 (paper)

A study of pension plans, old people's homes, and almshouses.

BIRTH AND DEATH RATES OF THE FEEBLE MINDED. *Eugenics Record Office Bulletin No. 26.*
By Charles V. Green. *Eugenics Record Office*
25 cents *Cold Spring Harbor, Long Island*
6 x 9; 34 (paper)

The author finds that the birth-rate among the feeble-minded is high and that the number of offspring much more than replaces the probable parental group.

LEARNING AND GROWTH IN IDENTICAL INFANT TWINS. *An Experimental Study of the Method of Co-Twin Control. Genetic Psychology Monographs Vol. VI, No. 1.*

By Arnold Gesell and Helen Thompson.

Clark University Press

$2.00 *Worcester, Mass.*

6½ x 9¾; 124 (paper)

This interesting study of a pair of identical twins during the first year and a half of their lives leads to the general conclusion that the preponderant influence in the determination of infant behavior pattern is the maturation of the neural structures. "There is no conclusive evidence that practice and exercise even hasten the actual appearance of types of reaction like climbing and tower building." One of the twins was trained and the other kept as control without training. At age 50 weeks after four weeks of training twin *T* climbed an experimental staircase "with avidity and without assistance." At 52 weeks she climbed the staircase in 26 seconds. But twin *C*, without any previous training whatever, climbed the same staircase unaided at 53 weeks in 45 seconds.

THE PEOPLING OF AUSTRALIA.

By W. E. Agar, Henry Barkley, H. Benham, J. B. Brigden, A. H. Charteris, H. W. Cilento, J. Lyng, E. T. McPhee, P. D. Phillips, C. H. Wickens, G. L. Wood. Edited by P. D. Phillips and G. L. Wood. With a Foreword by J. G. Latham.

The Macmillan Co.

$2.50 4¾ x 7¼; xi + 300 *New York*

A collection of eleven articles, some of which have already appeared elsewhere. The authors are all Australians, either university lecturers and professors or public servants whose work has a direct bearing on the problems which are confronting Australia at the present day in regard to its development. Such problems are discussed as the absorptive capacity of the continent for population, the optimum size of population, urbanization, white settlements in tropical Australia, general quality of the population, immigration policy, climatic factors affecting the distribution of peoples, etc. Australia's present population is placed at 6 millions. It is something over 140 years ago that the first white settlement was made on the continent. It has been estimated that at that time the number of natives probably did not exceed 150,000. To-day the number is hardly more than 60,000. Of the present population 98 per cent are British subjects by birth, 1.3 are black, 0.45 yellow and 0.25 brown. Concerning the racial constitution of the Australians it is estimated that 82 per cent of the white population is Nordic, 13 per cent Mediterranean and 5 per cent Alpine. Under the Immigration Restriction Act quotas have already been established.

HUMAN BIOLOGY AND RACIAL WELFARE.

Contributors: Walter B. Cannon, Alexis Carrel, Edmund V. Cowdry, Edwin G. Conklin, Charles B. Davenport, John Dewey, Haven Emerson, John F. Fulton, William K. Gregory, William Healy, Ales Hrdlicka, Ellsworth Huntington, Paul A. Lewis, Archibald B. Macallum, Elmer V. McCollum, Robert A. Millikan, George H. Parker, Harry A. Overstreet, Raymond Pearl, Earle B. Phelps, Sir Humphrey Rolleston, Henry N. Russell, Sir Chas. S. Sherrington, William M. Wheeler, Clark Wissler, Robert M. Yerkes, Hans Zinsser.

Edited by Edmund V. Cowdry, with an Introduction by Edwin R. Embree.

Paul B. Hoeber, Inc.

$6.00 net $5\frac{1}{8}$ x $9\frac{1}{4}$; xviii + 612 *New York*

This volume, with its distinguished list of contributors, is intended for students about to specialize, and for mature readers who wish to learn something of what is now known about the human animal. The chapters are naturally somewhat uneven in quality, but there is good and interesting reading in a large number of them. The second part of the title might lead one to expect a good deal of uplift, an expectation hardly realized. Most of the contributors dodge the uplift, and even the last two chapters, "The Purposive Improvement of the Human Race" (Conklin) and "The Intentional Shaping of Human Opinion" (Overstreet) are singularly moderate in the hopes they hold out for any improvement of the race. There are short reference lists for the different chapters, and an index.

ZOOLOGY

THE BOOK OF BIRD LIFE. *A Study of Birds in Their Native Haunts; with Photographs by the Author.*

By Arthur A. Allen.

D. Van Nostrand Co., Inc.

$3.50 6 x 9; xix + 426 *New York*

Bird lovers and amateur naturalists will find this book delightful reading. It is in no sense a manual. Rather has the author sought to introduce the bird to the reader as a living animal. The first part deals with "the laws that govern the occurrence of birds in any locality; their relation to the environment and to each other; the principles underlying song, courtship, nesting, and other habits; the nature of the many nice adaptations of structure, and the explanation of the varied colors of birds together with the relations of birds to man." The second part deals with methods of studying the bird in its environment. The book contains many excellent illustrations showing the bird in its natural environment; lists of suggested readings are given, there is a chapter on "Suggestions for the intensive study of a species" and an index.

IN THE ZOO. *Representing Twenty-Seven years of Observation and Study of the Animals in the New York Zoological Park.*

By W. Reid Blair. Foreword by Madison Grant. Photographically Illustrated by Elwin R. Sanborn. Charles Scribner's Sons

$2.50 $5\frac{3}{4}$ x 8; xii + 195 *New York*

In this book the Director of the New York Zoological Park tells how his charges are cared for, how they are fed, and how medical, surgical and dental treatment is administered to them. The book is amusingly written and well illustrated. Although it is intended primarily for the general reader, much of it, especially the medical and surgical portion, will be of interest to the professional biologist.

LABORATORY EXERCISES IN ZOÖLOGY. *A Practical Student's Manual for Classes in Animal Biology.*

By William M. Barrows. World Book Co.

84 cents *Yonkers-on-Hudson, N. Y.*

$5\frac{3}{8}$ x 8; vi + 103

This excellent laboratory manual deals largely with living forms. A useful book to place in the hands of students of elementary biology.

THE GALL WASP GENUS CYNIPS. *A Study in the Origin of Species. Waterman Institute for Scientific Research Publication No. 42; Contribution from the Department of Zoölogy, Indiana University, No. 220 (Entomological Series No. 7).*
By Alfred C. Kinsey.
Indiana University Bookstore
$2.50 (paper) 5¾ x 9; 577 *Bloomington*
$3.00 (cloth)

The author of this intensive study of the genus *Cynips* has performed the arduous task of examining over 17,000 insects and 54,000 galls. The larger part of the book, Part II, is taken up with systematic data, illustrations, key, etc. Part I is devoted to a discussion of the bearing which the results of this investigation have upon the problems pertaining to the origin of species. The author finds that mutations in *Cynips* "have been the chief source of new species, but only when they are isolated from close relatives with which they might have interbred. Altho hybrid individuals prove common, and local colonies which have arisen by hybridization between related species are not unknown, the isolation of such hybrid populations to form species seems to have occurred in only a few instances in this genus." A taxonomic revision of the genus has been made. As redefined the group is a "homogeneous unit delimited by insect morphology, gall characters, host relationships, life histories, and geographic distribution." Of the 93 species in the group 45 have been previously described, and 48 are new. Six cases of alternation of generations have been added to the five already recorded.

The book is well illustrated with distribution maps and figures of the insects studied—something over 400 in all. There is a bibliography pertaining to the general biological discussion in Part I, and an index.

AQUATIC MAMMALS. *Their Adaptations to Life in the Water.*
By A. Brazier Howell. *Charles C. Thomas*
$5.00 postpaid *Springfield, Ill.*
6 x 8¾; xii + 338

In this book Dr. Howell considers the many remarkable adaptations of aquatic mammals to their life in the water. Being designed for a wider public than the anatomists and mammalogists, the book is written "in an essentially nontechnical manner." There is, however, no attempt to jazz up the subject. There is a bibliography and an index.

REPORT OF THE UNITED STATES COMMISSIONER OF FISHERIES *for the Fiscal Year 1928, with Appendixes. Part II.*
U. S. Government Printing Office
$1.65 5¾ x 9; iv + 670 *Washington*

This part of the report consists of the *Check List of the Fishes and Fishlike Vertebrates of North and Middle America North of the Northern Boundary of Venezuela and Colombia*, by David Starr Jordan, Barton Warren Evermann, and Howard Walton Clark, a revision of Jordan and Evermann's Check List of 1896. The number of species enumerated has increased from 3,100 to 4,139. There are indexes of common and scientific names. In the interesting but brief discussion of the origin of species the authors conclude that "it does not appear that any species of fishes have arisen by mutation or from hybridization, though the latter possibility is greater than the former."

DIE TIERWELT DER NORD- UND OSTSEE. *Lieferung XVI. Lieferung XVII. Edited by G. Grimpe and E. Wagler. Akademische Verlagsgesellschaft m.b.H.*

Lief. XVI, 21 marks *Leipzig*
Lief. XVII, 13.50 marks
6 x 8½; 244 (paper)
158 (paper)

These two parts of this valuable work, previous numbers of which have been noted in these columns, deal with the following groups: *Rotatoria*, by A. Remane; *Ostracoda*, by W. Klie; *halophilic and halobiontic Coleoptera*, by H. v. Lengerken; *Peridinia*, by N. Peters; *Scyphozoa*, by Th. Krumbach.

A CONSPECTUS OF THE MARINE AND FRESH-WATER CILIATA BELONGING TO THE SUBORDER TINTINNOINEA, WITH DESCRIPTIONS OF NEW SPECIES PRINCIPALLY FROM THE AGASSIZ EXPEDITION TO THE EASTERN TROPICAL PACIFIC 1904–1905. *University of California Publications in Zoology, Vol. 34.*
By Charles A. Kofoid and Arthur S. Campbell.
University of California Press
$5.00 7 x 10¾; 403 *Berkeley*

This report is based upon material from the eastern part of the Pacific Ocean including the north temperate, tropical and south temperate regions. The collections were made by the Agassiz expedition of 1904–1905, various expeditions of the U.S.S. Albatross, as well as by individual members of the Scripps Institution and the University of California. This particular protozoan group is treated as a whole. It includes 51 genera, including 23 which are new. There are listed 276 new species while 38 others are given new names. Figures of all the species are included in the text, there is a lengthy literature list and a detailed index.

RECORDS OF CHANGES IN COLOR AMONG FISHES. *Zoologica, Vol. IX, No. 9.*
By Charles H. Townsend.
New York Zoological Society
$1.85 *Zoological Park, N. Y. City*
6¼ x 9½; 58 (paper)

In this beautifully illustrated article the Director of the New York Aquarium records the color phases of the tropical fishes in the Aquarium.

THE FRESH WATER MOLLUSCA OF WISCONSIN. *Part I. Gastropoda. Part II. Pelecypoda.*
By Frank C. Baker.
Wisconsin Academy of Sciences, Arts, and Letters
$3.00 *Madison*
Part I. 6½ x 9½; xx + 507 + 28 plates
$3.00
Part II. 6½ x 9½; vi + 495 + 77 plates
(paper)

In this excellent monograph "the account of each species is given under several headings, including the shell, animal, parts of its anatomy (genitalia, jaw, radula), its ecology, its distribution by drainage systems in the State and remarks concerning the chief features of its variation, value, or general interest." There is a bibliography of 23 pages, a glossary and an index. Mr. Baker agrees with Coe that the "environment permits and directs evolution but does not cause it."

BOTANY

THE PENICILLIA.
By Charles Thom. With the assistance of Margaret B. Church, O. E. May and M. A.

Raines. *The Williams and Wilkins Co.*
$10.00 5⅞ x 9; xiii + 644 *Baltimore*

A highly important contribution to the literature of mycology. The molds of Penicillia cause widespread depredation throughout the world. They rot fruit, vegetables and meat; discolor fibers, wood, paper stock and stored paper; grain in storage is frequently injured by them, and they contaminate laboratory cultures, soft drinks and bottled waters. The best that can be said of them is that they produce Camembert and Roquefort cheese. But in addition to all the havoc which they work, for the investigator they have an added sin: they are extremely difficult to classify. The author of this book has devoted many years in an endeavor to disentangle this problem. Ultimately he based his classification on "delimitation of groups presenting common morphological and cultural characters." Concerning the difficulties which Penicillia present, he says,

> Alive and actually growing, they have individuality as pronounced as their capabilities for evil, but the elements of that individuality, color, odor, and habit of growth, are as evanescent as frost designs on a window pane in winter. To lay a foundation for a permanent knowledge of this lot of molds, the whole range of morphology and physiology must be searched for marks of separation stable enough, and sharply enough marked to convey to the reader a definite picture of the organisms studied. Then organism by organism they must be fitted into the scheme of classification to form a consistent and interpretable whole.

The work falls into two sections. The first ten chapters are devoted to a discussion of the problems, activities, and uses of the organism. The remaining seventeen are taxonomic. There are numerous illustrations, a lengthy bibliography, a general index and an index to species.

PLANT COMPETITION. *An Analysis of Community Functions. Carnegie Institution of Washington Publication No. 398.*
By Frederic E. Clements, John E. Weaver and Herbert C. Hanson. Carnegie Institution of
$3.25 (paper) *Washington, D. C.*
$4.25 (cloth)
6¾ x 10; xvi + 340

This important monograph is the second in a series dealing with the functions of the plant community as a complex organism. The first, "Experimental Vegetation," appeared in 1924. It is the plan of the authors to prepare other volumes dealing with reaction, coaction, adaptation, and migration and invasion. The studies on competition and reaction reported in the present volume have been made under both natural and controlled conditions "involving the utilization of climax and seral communities in nature, field crops and greenhouse control." The first chapter deals with a "History of the competition concept;" then follow sections on "Transplant cultures in sub-climax prairie," "Transplant cultures in true prairie," "Supplementary studies of competition in the prairie," "Competition in the ecotone between woodland and prairie," "Competition in cultivated fields," "The relative importance of the factors in competition" and "Functional studies in control cultures." The work is excellently illustrated with many figures and photographic reproductions, and contains 132 tables exhibiting growth, analyses, etc. There is a lengthy bibliography.

FLORA OF THE HERMIT SHALE, GRAND CANYON, ARIZONA. *Carnegie Institution of Washington Publication No. 405.*

By David White. *Carnegie Institution of*
$2.50 (paper) *Washington, D. C.*
$3.50 (cloth)

6¾ x 10; 221

The first section of this study is devoted to a description of the geological environment, the second, to the composition, age and relations and the third, to the description of the Hermit flora. The flora points to a semi-arid climate with a long dry season during the Hermit time. Altogether 34 species of fossil plants are described. Insect wings were found, numerous foot prints of vertebrates and three fossil forms which are probably of animal origin. The investigator expects further study to yield many more species of plants. The photographic plates, of which there are 51, are remarkably fine.

BIBLIOTHECA BOTANICA. *Heft 99. Geschichte und Geographie der Veronica-Gruppe Megasperma.*
By Ernst Lehmann.
E. Schweizerbart'sche Verlagsbuchhandlung
19 marks *Stuttgart*

9 x 12½; 55 + 1 table (paper)

An interesting exposition of the problems of speciation which are presented by the European species of the genus *Veronica*, the common "speedwell." The facts regarding the history of the genus and the geographical distribution of the species in the *Megasperma* group are well presented, and they clearly demonstrate that the geneticist has here a fine opportunity to try his hand at unravelling an exceedingly puzzling problem of evolution. Why is it that, in spite of the ubiquitous occurrence of the weed, and its great facilities for dispersion, there exist well marked, and clearly differentiated geographical varieties, in some cases even overlapping in their ranges?

PLANT BIOLOGY. *An Outline of the Principles Underlying Plant Activity and Structure.*
By H. Godwin. *University Press*
8s. 6d. *Cambridge*
$2.90 *The Macmillan Co.*
New York

5½ x 7½; x + 265

A text book for first-year medical and biological students. Especial emphasis is laid on the physiological point of view and a consideration of the simpler characters of the physicochemical background of plant life. The book is well illustrated and indexed.

BACTERIAL METABOLISM.
By Marjory Stephenson.
Longmans, Green and Co.
$7.00 6 x 9⅝; xi + 320 *New York*

This book belongs to the excellent series of monographs on biochemistry, edited by R. H. A. Plimmer and Sir F. G. Hopkins. In the present treatise the author's aim is to present facts which will lead to an understanding of "bacteria as living organisms apart from their rôle as disease germs or the bearer of commercially important catalysts." Although Miss Stephenson considers that she has doubtless included material which later may prove irrelevant to the subject, as well as omitted important facts, her book shows that she has made an extraordinarily careful and discriminating study of the physiology of bacteria. In the text are 83 tables. There is an appendix on the "Barcroft Differential Manometer" and a bibliography of about 800 titles. The book is well indexed.

VEGETATIVE PROPAGATION FROM THE STANDPOINT OF PLANT ANAT-

OMY. *U. S. Department of Agriculture Technical Bulletin No. 151*
By J. H. Priestley and Charles F. Swingle.
U. S. Government Printing Office
35 cents *Washington*
5¾ x 9⅛; 99 + 24 plates (paper)

A report of a technical study of vegetative propagation, primarily of the internal factors involved, made for the purpose of obtaining a better understanding of those plants which offer more or less difficulty in propagation by this method. The work has been limited to a study of the phenomenon as it occurs in the flowering plants, usually in the dicotyledons. A detailed analysis of the anatomical basis of vegetative propagation is given. Numerous illustrations are included in the text and a literature list of 190 titles is given.

BERGEY'S MANUAL OF DETERMINATIVE BACTERIOLOGY. *A Key for the Identification of Organisms of the Class Schizomycetes. Third Edition.*
By David H. Bergey. Assisted by a Committee of the Society of American Bacteriologists, Francis C. Harrison, Robert S. Breed, Bernard W. Hammer, Frank M. Huntoon, with an Index by Robert S. Breed.
The Williams and Wilkins Co.
$6.00 5⅞ x 9; xviii + 589 *Baltimore*

The third edition of this standard manual, which is indeed virtually indispensible for any bacteriologist, has been greatly enlarged, and rather extensively revised. Over 200 additional organisms are included, two new tribes are recognized, as well as several new genera. A solid useful piece of work.

GROWTH AND TROPIC MOVEMENT OF PLANTS.
By Sir Jagadis Chunder Bose.
Longmans, Green and Co.
$8.40 *New York*
5½ x 8¾; xxix + 447

This volume is the continuation and, according to the publisher's statement the completion, of the distinguished author's investigations of the movements of plants. A wide range of subjects is discussed, the data being obtained by the use of the author's automatic high magnification crescograph, and various modifications of it. The general conclusion is:

> The fundamental principle is that growth is retarded by strong and accelerated by weak stimulation of whatever kind. Closely connected with it is the further principle that direct stimulation retards and indirect stimulation accelerates the rate of growth: this is the essential feature of the mechanism of tropisms. There is no longer any ground for assuming distinct irritabilities, such as the phototropic and the geotropic, or negative and positive phototropism and geotropism: these terms may remain as merely descriptive of the visible response. There is but one irritability of the growing organ which responds to all stimuli that may act upon it, and in essentially the same manner.

This, like many of Dr. Bose's books, is perhaps quite as interesting from the standpoint of the philosophy of scientific methodology as for its biological results. There is presented to the reader a series of separate single experiments, from each of which single experiments a principle or law is deduced, some of extremely far reaching significance. Doubtless Dr. Bose actually performed *many* experiments like each one of the single ones he presents to the reader. Also, doubtless (unless all other biologists are working in a state of profound delusion) there was more or less *variation* in the results of a set of repeated experiments of the same kind. But of variation and divergences in the results of repeated experiments, which are, to the author's great pride and satisfaction, of a more precise and delicate quantitative character than almost any other biological

experiments ever made, Dr. Bose says never a word except to suggest occasionally that if divergences from the stated result should occur they would be due to errors of technique. Perhaps it is this seventeenth century rationalistic attitude, with its unquestioning trust in the crucial experiment carefully measured, and its correlative naïve neglect of differences, variations, and divergences, which has, in part, brought it about that plant physiologists generally appear not to accept Dr. Bose's results with anything approaching ardent enthusiasm.

On the other hand, it must be said that there are not a few present day biologists whose philosophical *summum bonum* is seventeenth century rationalism, pure and undefiled, though doubtless some of them would dislike to have their attitude so roughly characterized. To them Dr. Bose's work must, or at least ought to, seem good. There is probably a sweet satisfaction derivable from a real privity with God in His ability to "understand" natural phenomena.

In any case all biologists cannot but admire the extremely delicate and precise mensurational technique which Dr. Bose has brought to the service of biology.

MORPHOLOGY

LABORATORY GUIDE TO VERTEBRATE DISSECTION *for Students of Anatomy.*
By A. B. Appleton. *The Macmillan Co.*
$6.50 *New York*
$4\frac{3}{4}$ x $7\frac{1}{4}$; xix + 152

A guide to practical comparative anatomy which has been in use for several years in the University of Cambridge. The types dealt with are the lamprey, the dogfish, *Necturus*, the lizard, and the dog.

DIE FOSSILEN GEHIRNE.
By Tilly Edinger. *Julius Springer*
36 marks $6\frac{3}{8}$ x $9\frac{1}{2}$; 249 *Berlin*

In this thorough treatise on endocranial casts are collected the known data by classes and orders of the vertebrates. The author is critical of Marsh's "general law of brain growth." There is an annotated bibliography and an index.

WIE SOLLEN WIR ELITEGEHIRNE VERARBEITEN?
By C. v. Economo. *Julius Springer*
6.90 marks $6\frac{3}{8}$ x $9\frac{1}{2}$; 87 (paper) *Berlin*

A description of technique for the measurement and histological examination of the brain.

PHYSIOLOGY AND PATHOLOGY

ANTIVIRUSTHÉRAPIE. *Applications à l'Ophtalmologie, l'Oto-Rhino-Laryngologie, la Stomatologie, l'Entérologie, l'Urologie, la Gynécologie et l'Obstétrique, la Dermatologie, la Chirurgie, la Médecine Vétérinaire, la Sérothérapie Locale.*
By A. Besredka. *Masson et Cie*
40 francs *Paris*
$5\frac{5}{8}$ x 9; viii + 430 (paper)

The use of vaccines for the cure of disease has been largely disappointing. Now comes Besredka to tell us that the reason is that in all cases we have been injecting the vaccines subcutaneously when actually we should have been applying them to the particular tissue the resistance of which we wished to raise. Thus, if we wish to cure boils we should inject the vaccine into the skin and if we wish to cure an enteritis we should give vaccines and bacterial filtrates by mouth. Besredka describes a number of ways in which

vaccines and what he calls antiviruses can be made. Pasteur showed that when bacteria are grown in a culture medium substances are produced which are inimical to further growth. Besredka obtains these substances in more concentrated form by filtering out the bacteria and then seeding the medium again. The antivirus so produced can then be used to combat the growth of bacteria in the body.

The present volume summarizes the reports of many investigators who claim to have obtained good results with the help of the new methods of vaccination. One hopes that it is all true; the theory is an attractive one and certainly the experiments should be carefully repeated. Unfortunately so many in the past have cried, "Eureka," that Besredka cannot complain if many of his readers refuse immediately to believe and to get excited. It is to be hoped that many will read this book, that some will repeat the experiments, and that they will then report their results.

MAGICIAN AND LEECH. *A Study in the Beginnings of Medicine with Special Reference to Ancient Egypt.*
By Warren R. Dawson.
Methuen and Co., Ltd.
7s. 6d. net *London*
$4\frac{3}{4} \times 7\frac{1}{2}$; xiii + 159

The author of this interesting book has gone to the original medical documents for his material. He gives only a brief summary of what he has gleaned from the study of numerous papyri but it is a progressive picture of the evolution of medicine from early magic. In the course of time some of the early magicians perceived the wisdom of increasing their repertoire. Doses of substances were administered internally as well as externally along with the magic. The more efficacious of these doses naturally tended to survive their more fantastic fellows and eventually there were healers who confined themselves entirely to the practice of administering "medicines." Even so far back as the Pyramids there was the title of "Royal Physician—interpreter of a difficult science." The magician, however, was never driven out of business. Of special interest are the chapters on "The first medical books" and "Drugs and doses." We find as an ointment for a troublesome scalp the following: "Fat of a lion, 1 (part); fat of a hippopotamus, 1; fat of a crocodile, 1; fat of a cat, 1; fat of a snake, 1; fat of an ibex, 1. Mix into one mass; anoint the head therewith." Animals whole or in part played an important place in Egyptian prescriptions, the gall of animals being especially fancied as a medicine. The number of vegetable drugs was very large and we find castor oil a great favorite. Over 2000 prescriptions occur in the medical papyri of Pharaonic times.

Much time has been devoted by the author to the study of mummification. He believes that its importance in the development of medicine can hardly be overestimated, not only because of the knowledge which the early Egyptians acquired of human anatomy but because "it familiarized the popular mind for over twenty centuries with the idea of cutting the dead human body." This fact made it possible for the "Greek physicians of the Ptolemaic age to begin, for the first time, the systematic dissection of the human body, which popular prejudice forbade in all other parts of the world."

LES ÉRYTHRÉMIES DE L'ALTITUDE. *Leurs Rapports avec la Maladie de Vaquez. Étude Physiologique et Pathologique.*

By Carlos Monge. *Masson et Cie*
22 francs *Paris*
6⅜ x 10; xi + 135 (paper)

If there is one place in the world in which the diseases due to living at high altitudes could be studied it should be Peru, and Dr. Monge is Professor of Internal Pathology at the University of Lima. There have been a number of scientific expeditions to the Alps, Pike's Peak, Peru, and the Sierras of California to study the changes which take place during the acclimation of individuals to high altitudes, but here is a book which deals more particularly with the chronic disturbances which appear in persons who live for years in the mountains. The main thesis of Dr. Monge is that in certain persons there is an insufficiency in the permeability of the lung to oxygen, an insufficiency which makes it difficult or impossible for them to become acclimated. He believes that mountain sickness is an acute form of erythremia. He describes also two chronic forms, one of which closely resembles Vaquez' disease. The book should be of great interest to all those who are concerned with the problems of respiration.

THE OCCULT CAUSES OF DISEASE. *Being a Compendium of the Teaching Laid Down in His "Volumen Paramirum" by Bombastus von Hohenheim, Better Known as Paracelsus.*

By E. Wolfram *Rider and Co.*
(*done into English by Agnes Blake*).
6 shillings 4⅞ x 7⅜; 296 *London*

Herr Wolfram interprets the doctrines of Paracelsus as being a form of Rosicrucianism. But is there any good evidence that Rosicrucianism existed before the seventeenth century? The book might serve as a storehouse of fallacies for a class in logic to cut their teeth on. Thus cholera and arsenic poisoning are identified with each other because of the similarity of their symptoms. After reading the book we are still of the opinion that the importance of Paracelsus lies not in his occultism but in his turning from authority to the first-hand study of nature.

LES ACROCYANOSES. *Troubles Vasculaires Cutanés d'Origine Nerveuse, Végétativ ou Centrale.*

By Fernand Layani. *Masson et Cie*
32 francs 6¼ x 9½; iv + 282 (paper) *Paris*

A syndrome is described which consists of cyanosis, generally of the extremities, associated with coldness of the parts affected, and secretory and trophic disturbances which never go so far as to produce gangrene. The author feels that this disease can be differentiated from those which now go by the names of Raynaud and Buerger. He believes that the primary disturbance is probably in the endocrine system and he attempts to cure it by giving to the patients extracts of the various glands of internal secretion. There is a good review of the European literature on the subject but, unfortunately, the author does not seem to have been aware of the recent work of George Brown and other Americans. The book should be of great interest to all those who deal with this problem of vascular spasm.

THE CANCER PROCESS. *An Examination of the Factors which Induce New Growth.*

By J. J. M. Shaw. *E. and S. Livingstone*
1 shilling net *Edinburgh*
5¾ x 9; 16 (paper)

In the form of a brief, essentially dogmatic, statement without documentation

or systematic presentation of evidence, the author develops the thesis that "*Cancer is caused by prolonged contact between the cells of living tissue and any substance which possesses these three properties: VISCOSITY, INSOLUBILITY in tissue fluids, and TOXICITY to cell life.* These three properties are found in concomitance in every substance which is capable of producing the cancer cell. Be it tar or stale sebaceous matter, shale oil or foul sputum, ethereal extract of tobacco or effete muco-pus, paraffin, applied and injected, or the cholesterin, lecithin, and fibrin of old extravasated blood, the trio of properties is always exhibited." The reasoning is well-knit and in some degree persuasive, but probably not quite adequate to support the heavy burden of so wide a generalization.

LEPROSY. *Survey Made in Forty Countries (1924–1927).*
By H. C. de Souza-Araujo.
Oswaldo Cruz Institute
$4.00 *Rio de Janeiro*
7½ x 11¼; 400 (paper)
(May be obtained from D. Appleton, New York; W. B. Saunders Co., Philadelphia; Cassel and Co., London; Masson et Cie, Paris; The Macmillan Co. of Canada, Toronto.)
(The total revenue of the Portuguese and English issues is reserved to form the fund of the Societas Internationalis Leprologiae, of Bergen, Norway.)

This monograph will interest many people. Physicians, hygienists, all who are concerned with making laws governing leper colonies as well as workers among the lepers will find it invaluable as a source book. The extent of the material presented is indicative of the labor and care which the author has expended in making the survey. The work includes 66 tables dealing with statistics and numerous illustrations. At the conclusion of each section a bibliography is given of the literature which has appeared concerning leprosy in that particular country.

THE PHYSIOLOGY OF ORAL HYGIENE AND RECENT RESEARCH. *With Special Reference to Accessory Food Factors and the Incidence of Dental Caries.*
By J. Sim Wallace.
Baillière, Tindall and Cox
10s. 6d. net 5½ x 8½; vii + 228 *London*

A collection of papers and addresses giving Dr. Wallace's reasons for concluding that dental caries is caused by the acid fermentation of carbohydrates and not by lack of vitamin D.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 311.* Containing following articles: *Methoden zur Messung der Oberflächenspannung*, by A. Gyemant; *Methoden zur Bestimmung des elektrischen Widerstandes*, by Marie Wreschner; *Die Potentiometrie*, by E. Mislowitzer.
Urban und Schwarzenberg
6 marks 7 x 10; 107 (paper) *Berlin*

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 323. Photochemische Arbeitsmethoden im Dienste der Biologie.*
By Ivan Plotnikow.
Urban und Schwarzenberg
13 marks 7 x 10; 260 (paper) *Berlin*

These two numbers of the Abderhalden *Handbuch* maintain the high standard of the work as a whole. The second of them, dealing with photochemical methods, will be particularly useful for its thorough discussion of light filters, and the technique of photometry.

BIOCHEMISTRY

OXIDATION-REDUCTION POTENTIALS.

By L. Michaelis. Translated from the German Manuscript by Louis B. Flexner.
J. B. Lippincott Co.
$3.00 *Philadelphia*
5¼ x 8; xiii + 199

This monograph, by a distinguished worker on problems of hydrogen ion concentration and oxidation-reduction potential, will be useful to the biochemist.

DIE KOLLOIDE IN BIOLOGIE UND MEDIZIN.

By H. Bechhold. *Theodor Steinkopff*
32 marks (paper) *Dresden*
35 marks (bound)
6¼ x 9; xii + 586

This fifth edition of a standard treatise on colloids for biologists has been practically completely rewritten and greatly enlarged. It is abundantly and well illustrated, meticulously documented, and well indexed. The subject is treated under four general heads: I. Introduction to colloid research; II. Biocolloids; III. The organism as colloid system; IV. Toxicology, pharmacology, therapeutics, and microscopical technique. It is an excellent book.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 315.* Containing following articles: *Gasometrische Mikro-Kjeldahl-Stickstoffbestimmung,* by Donald D. van Slyke; *Methoden zur Untersuchung des Stoffwechsels von Leukocyten und Thrombocyten,* by Walter Fleischmann; *Praktisches Verfahren bei Ernährungsversuchen,* by Arthur H. Smith and Lafayette B. Mendel.

Urban und Schwarzenberg
5 marks 7 x 10; 92 (paper) *Berlin*

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 317. Fermentforschung.* Containing following articles: *Spezifische Nucleasen,* by Fr. Chrometzka and A. Schittenhelm; *Bestimmung von Harnstoff durch gasometrische Messung des durch die Einwirkung von Urease gebildeten Kohlendioxydes,* by Donald D. van Slyke; *Myrosinase,* by Fritz Wrede; *Chlorophyllase,* by Richard Willstätter; *Phytophosphatasen,* by Heinrich Lüers; *Gewinnung von proteolytisch einheitlichem Trypsin und Erepsin aus Pankreas und Darm,* by Ernst Waldschmidt-Leitz; *Trennung der Hefeproteasen,* by W. Grassmann; *Über Luciferase von leuchtenden Tieren,* by E. Newton Harvey.

Urban und Schwarzenberg
8 marks 7 x 10; 143 (paper) *Berlin*

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 322.* Containing following articles: *Methoden zur Untersuchung des Energieumsatzes in Muskeln und Nerven,* by J. L. Parkinson; *Die Arbeitsmaschine Johanssons,* by Ernst Abramson.

Urban und Schwarzenberg
7 marks 7 x 10; 116 (paper) *Berlin*

These three numbers of the Abderhalden *Handbuch* of biological technique deal with various biochemical procedure, as indicated by the titles. The article by Smith and Mendel in *Lief.* 315 will be found useful by many workers for the large number of experimental diets for specific purposes which it contains. The interest of the other articles in these three *Lieferungen* is mainly special to the biochemist and physiologist.

MIKROMETHODIK. *Quantitative Bestimmung der Harn-, Blut- und Organbestandteile in kleinen Mengen für klinische und experimentelle Zwecke.*

By Ludwig Pincussen. *Georg Thieme*
7.50 marks *Leipzig*
5¼ x 7⅞; 225 (paper)

The fifth revised and enlarged edition of a standard guide to microchemical technique. An index has also been added.

SEX

THREE CONTRIBUTIONS TO THE THEORY OF SEX. *Fourth Edition. Nervous and Mental Disease Monograph Series No. 7.*

By Sigmund Freud (Authorized translation by A. A. Brill).

Nervous and Mental Disease Publishing Co.
$2.50 *New York and Washington*
6 x 9; xiv + 104

Rereading this reprint of a pioneer treatise, which has become a classic in the course of the twenty odd years since it first appeared, leaves one with two outstanding and vivid impressions; first, that Freud has made an enormous and profound contribution to an understanding of the meaning of sex. Second, that his grasp and penetration of the workings of the human mind make the academic psychologists look silly, with their petty and precious tiddlings-about in the laboratory striving to measure things, without the faintest apparent understanding of the subtlety, the complexity, the integrated manifoldness of the object of their study. Thanks to Freud and his students and followers it has been recognized for some time by impartial biological spectators on the side lines that academic psychology would do well to go to school to the despised psychiatrists for awhile. Out of all the bitter controversies which have gone on around him Freud emerges as a very great man, with many of the earmarks of genius. The publishers do well to keep this little volume in press.

LA GÉNÉRATION HUMAINE. (*Les secrets de la vie*).

By G. Mozy. *Librairie Le François*
10 francs 4¾ x 7⅜; 152 (paper) *Paris*

The first of a series designed to tell the French what they ought to know about sex. Dr. Mozy is much impressed by the terrible effects of alcohol on the offspring. "*Les expériences de Stokar et Miss Craiy*" on guinea pigs are cited; also some remarkable figures purporting to give the results of clinical observation on human subjects. "When the father alone is alcoholic, 58 per cent of sterility, 22 per cent of still-born, 20 per cent of living children, but all ill, epileptic or sickly. When it is the mother, 25 per cent of sterility, 25 per cent of still-births, 50 per cent of normal subjects." Frankly we are from Missouri about these percentages until we know something more about how they were collected than Dr. Mozy vouchsafes us.

BIOMETRY

A SOURCE BOOK IN MATHEMATICS. *By David E. Smith.*

McGraw-Hill Book Co., Inc.
$5.00 5¾ x 9; xvii + 701 *New York*

The second of a series of source books in the history of the sciences. To the biometrician the most interesting of the sources are the correspondence of Fermat and Pascal on Probability, De Moivre on the Normal Curve, Legendre on Least

Squares, Chebyshev on his inequality and Laplace on the Normal Curve.

THE PRINCIPLES OF MEASUREMENT AND OF CALCULATION IN THEIR APPLICATION TO THE DETERMINATION OF DIOPHANTINE QUANTITIES. *Bureau of Standards Research Paper No. 145.*
By Edward W. Washburn.
U. S. Government Printing Office
10 cents $5\frac{7}{8}$ x 9; 26 (paper) *Washington*

The ordinary treatment of the theory of errors assumes that the unknown true value sought is a member of a continuum of "possible" values. In many problems, however, the true value is known to be a member of a set of discrete values, e.g. the positive integers. This paper gives a systematic treatment of such cases.

BIOMETRICAL STUDIES OF THE GROS MICHEL BANANA. *Part I. Biometrical Technique. Bulletin No. 17. Parts II and III. The Fruit. Bulletin No. 18. Part IV. The Vegetative Growth. Bulletin No. 19.*
By A. N. Hartman. *United Fruit Co.*
Boston
$8\frac{1}{2}$ x 11; Bulletin 17, iii + 40 (paper)
Bulletin 18, iv + 157 (paper)
Bulletin 19, iii + 39 (paper)

A careful and detailed study of variation and correlation of bunch weight and other characters of the banana as affected by type of soil and climatic conditions. Growth curves of the banana plant under various conditions are also given.

PSYCHOLOGY AND BEHAVIOR

CONFIGURATIONAL LEARNING IN THE GOLDFISH. *Comparative Psychology Monographs Vol. 7, No. 1, Serial No. 31.*
By F. Theodore Perkins and Raymond Holder Wheeler. *The Johns Hopkins Press*
$1.00 $6\frac{3}{4}$ x 10; 50 (paper) *Baltimore*

This study of the learning processes of goldfish was made to determine to what extent they would exhibit "insightful" activity under controlled conditions. Briefly the method of procedure was as follows. Compartments with definite light intensities were placed in aquaria in such a way that the fish were blocked off in a small area. The only way of escape was for the fish to enter one of the compartments. In the different groups of experiments the number of compartments varied and their positions shifted. Also there was a change of light intensities which varied from double bright, bright, medium, dim to dark. Food in the compartments was used as a lure. The fish were trained to choose a light of a certain intensity, being allowed to feed only in the compartment so lighted. As a means of shock a stick was stirred vigorously when the wrong compartment was entered.

Some of the conclusions which the authors draw regarding their work are as follows:

"Goldfish readily learn to discriminate between different degrees of light intensities (possibly degrees of yellow)."

"These animals seem able to detect a 'constant relationship' between the lights when the intensities are shifted upward or downward, thus indicating that their responses are configurational, or structured."

THE PSYCHOANALYSIS OF THE TOTAL PERSONALITY. *The Application of Freud's Theory of the Ego to the Neuroses. Nervous and Mental Disease Monograph Series No. 52.*
By Franz Alexander. Authorized English translation by Bernard Glueck and Bertram D. Lewin. With a prefatory note by A. A. Brill.
Nervous and Mental Disease Publishing Co.
$3.50 *New York and Washington*
6 x 9; xx + 176

This book is based upon a series of nine lectures given at the Berlin Psychiatric Institute during 1924 and 1925, which have since been corrected and expanded. While primarily intended for the psychiatrist, and having for its main object the treatment of mental disease, the book will be found useful and interesting by the general biologist. The author's exposition of Freud's theory of the ego is extremely lucid and persuasive.

THE HUMAN MIND.
By Karl A. Menninger.
Alfred A. Knopf, Inc.
$5.00 6 x 9½; xxv + 447 *New York*

This book is intended to explain psychiatry in simple terms to doctors, lawyers, patients and other laymen. The presentation is largely in terms of case histories. The book is attractively written and will give the reader a better understanding of his own peculiarities and a greater tolerance for those of others. There are a bibliography and an index.

THE GROWTH OF REASON. *A Study of the Rôle of Verbal Activity in the Growth of the Structure of the Human Mind.*
By Frank Lorimer. Harcourt, Brace and Co.
$3.75 5½ x 8½; xii + 231 *New York*

To a mere biologist it appears that this book would have been a better one if its author had not tried to do so many things all at the same time. But to drive a three-horse team *abreast*, not tandem, made up of psychology, philosophy, and metaphysics, needs an old and wise hand and head. The book is primarily an interesting and sound review of the psychology of infancy and childhood. Mingled with this inherently straightforward and useful job are the author's own ideas of the philosophy of society and a sort of Whiteheadean metaphysic. No objection *per se* can be made to these latter elements, at least in a free country. But it would have been easier on the reader if the author had written three books instead of one, and stuck tight to the particular subject in hand in each one. Simplicity and straightforwardness are great and rare virtues.

THE FOUNDATIONS OF EXPERIMENTAL PSYCHOLOGY.
By H. Banister, Philip Bard, W. B. Cannon, W. J. Crozier, Alexander Forbes, Shepherd I. Franz, Frank N. Freeman, Arnold Gesell, H. Hartridge, Selig Hecht, James Q. Holsopple, Walter S. Hunter, Truman L. Kelley, Carney Landis, K. S. Lashley, Mark A. May, T. H. Morgan, John P. Nafe, George H. Parker, Rudolf Pintner, Eugene Shen, L. T. Troland, Clark Wissler. Edited by Carl Murchison.
Clark University Press
$6.00 6 x 9; x + 907 *Worcester, Mass.*

This book deals with all psychological problems which, in the judgment of the editor and his collaborators, promise a reward to experimental investigation. It is their intention to revise it often enough to be always abreast of progress and to change the list of problems as emphasis in psychology changes. Among the chapters in the present edition which will be

of special interest to the biologist are the Mechanism and Laws of Heredity, by T. H. Morgan, and The Study of Living Organisms by W. J. Crozier.

LA QUESTION DES TROPISMES
By Maurice Rose.

Les Presses Universitaires de France
75 francs 6 x 9⅜; vii + 469 *Paris*

This is an extremely thorough, complete, fully documented, and critical review of the literature of tropisms in plants and animals. The first and larger part of the book deals with the experimental facts; the second part with the general theories of tropistic responses, of which there are two, one associated with the name of Jennings, the other with that of Loeb. Both are thoroughly discussed, critically but fairly. Neither one is found to be entirely satisfactory. This volume will be an extremely valuable addition to any biological library.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 318.* Containing following articles: *Rationelle Organisation von biologischen Instituten;* and *Rationelle Technik der geistigen Arbeit des Forschers.*
By S. Tschachotin.

Urban und Schwarzenberg
6.60 marks 7 x 10; 106 (paper) *Berlin*

This fascicle is an example of the massive thoroughness of the great Abderhalden handbook of biological technique. The first part deals with the rational organization of a laboratory. It describes in great detail such matters as the best method of filing papers; keeping an inventory; arranging the library; card cataloging everything; keeping the accounts; spurring on the *Diener* to lead a higher and better life; making the perfect card to hang on the professor's door to show how long he will be out for lunch; the making of a research program; and so on. Mr. George Biological Babbitt now has his perfect *apologia.*

The second part tells the biologist how to arrange and control his intellectual and emotional affairs. Instructions are given about how he should do his reading; take his notes; make a table of his problems; order his time; and in other ways put in order the more mechanical aspects of what is optimistically called *geistige Arbeit.* Then the higher things are discussed. The biologist is urged to organize himself and told how to do it. He should live in the suburbs; wear light and porous clothing, avoiding particularly tight and stiff collars which interfere with the free circulation of the blood to the brain; practice deep breathing; eat meats and other foods rich in phosphorus if he be engaged in original creative work, but when occupied in critical work lean rather more to a vegetable diet; do a little in the gymnastic way; sleep well; and observe moderation and regularity in the gratification of the sexual appetite. In the psychic sphere the advice is equally detailed, but we can spare no more space. The final section deals with methods of favorably influencing intuition and inspiration.

PROHIBITION AND THE BIBLE.
By George Kilpatrick.

George Kilpatrick
15 cents *Bridgeport, Pa.*
3½ x 6; 23 (paper)

The importance of this little pamphlet in these troubled times is indicated by the

fact that it contains "every important reference in the Bible pertaining to the drink question." The author thinks that the prohibitionists do not play fair with the Bible, because they only "*partly* quote" and "distort the Book to suit their own narrow views." He makes a rather strong case for this view.

THE ELEMENTS OF LOGIC.
By Robert Latta and Alexander Macbeath.
The Macmillan Co.
$2.00 4¾ x 7¼; viii + 393 *New York*

A textbook of deductive and inductive logic.

THE SCEPTICAL BIOLOGIST.
By Joseph Needham.
W. W. Norton and Co., Inc.
$3.00 4¾ x 7¾; 270 *New York*

A series of pleasant essays on the philosophy and history of science. The philosophical essays are largely devoted to setting forth the virtues of a dilute eyewash patented by the author and alleged to be healing, which he labels Neo-mechanism; the historical sketches treat of S. T. Coleridge as a Philosophical Biologist, Julien de la Mettrie, and William Harvey and the Witches.

THE SEA.
By H. A. Marmer. *D. Appleton and Co.*
$3.00 5⅛ x 8; x + 312 *New York*

A popular treatise on the sea in which the author, Assistant Chief in the Division of Tides and Currents of the United States Coast and Geodetic Survey, leads the reader from a review of ancient sea lore and early maritime exploration down to the South Polar exploits of Amundsen and of the unfortunate Scott in 1911. There is summarized in an entertaining way what the science of oceanography has disclosed concerning the oceans of the earth. Some of the special topics are as follows: The depth of the sea, the bottom of the sea, the surface waters, the waters of the depths, waves of the sea, ocean currents, etc. This is a book which should prove especially useful in high school libraries. It contains 45 illustrations and figures and is well indexed.

A HISTORY OF SCIENCE *and Its Relations with Philosophy and Religion.*
By William C. D. Dampier-Whetham.
The Macmillan Co.
$4.00 6¼ x 9; xxi + 514 *New York*

Like Whewell, Dampier-Whetham is interested, not in presenting a catalogue of names of scientists, as is sometimes the case with historians of science, but in tracing the development of scientific thought. His viewpoint is that "by its inherent nature and fundamental definitions it [science] is but an abstraction, and that, with all its great and ever-growing power, it can never represent the whole of existence." There are passages in the book which the reader who shies at mathematical formulae will probably skip; nevertheless even he will be well repaid by reading this interesting and intelligently written history of science.

THE COST OF BIOLOGICAL BOOKS IN 1930

By JOHN R. MINER

Department of Biology, School of Hygiene and Public Health, Johns Hopkins University

AT THE end of the first volume of THE QUARTERLY REVIEW OF BIOLOGY (Vol. 1, pp. 605–608, 1926) was inaugurated the plan of reporting annually on the cost of the books which had been received during the year. The present paper continues this plan with the report of book costs for the year 1930.

For the purpose of price comparison the books are classified by origin as follows:

I. *The United States.* Here are put all books published by strictly, or primarily, American publishers. Naturally the majority of books reviewed during the year have had this origin just as in earlier years.

II. *Germany.* In the number of books sent in by publishers for review, Germany stands next to this country.

III. *English-American.* In this group are placed the books which are manufactured in the first instance in England by publishing houses which have *branches* under their own name (not merely agents) in this country. The American branch imports the books into this country and distributes them here, priced in dollars rather than shillings.

IV. *England.* In this class are placed books published in England, priced in shillings, and available in this country only by direct importation, by the individual or through an agent.

V. *France.* This group includes all books published in France and her colonies.

VI. *Other Countries.* Here are placed all books published in any other country than those specified above.

VII. *United States Government.*

VIII. *British Government.*

Table 1 gives, for each of these eight rubrics, (*a*) the total number of pages in the books received for review; (*b*) the total cost of these books in dollars, foreign prices being converted to dollars on the basis of the exchange prevailing when the books were received; (*c*) the average price per page *in cents*.

In order to facilitate comparison in respect of book prices, Table 2 has been prepared. In this table the following items are included: (*a*) the average price per page, in cents, for the years 1926–1930, (*b*) the absolute changes in average price per page, in cents, between 1926 and 1930, and between 1929 and 1930, a + sign denoting an *increase* in 1930 as compared with the earlier years, and a − sign denoting a *decrease*; (*c*) the percentage differences of the 1930 average price per page from those of 1926 and 1929, the + sign again indicating that the books were on the

TABLE 1

Prices of biological books, 1930

ORIGIN	TOTAL PAGES	TOTAL COST	PRICE PER PAGE
			cents
English-American	4,578	$87.50	1.91
Germany	11,573	210.14	1.82
British Government	1,514	17.98	1.19
England	5,960	67.55	1.13
United States	73,436	803.29	1.09
Other Countries	2,453	23.69	0.97
France	7,710	36.32	0.47
U. S. Government	4,081	12.30	0.30

average higher in price in 1930 than they were in the earlier years, and the − sign that they were lower.

The first point to be noted from Table 1 is the change from an increase to a decrease in the total amount of book material noticed in THE QUARTERLY REVIEW OF BIOLOGY. The total number of pages reviewed in 1930 is 111,305, a decrease of 20.6 per cent from 1929, but an increase of 34.8 per cent over 1926.

Turning to the prices given in Table 1 we find that the English-American books head the list, as in every previous year except 1928. It should, however, be remembered that these prices include both transportation and the United States tariff. For other groups the prices given refer to the country of publication and do not therefore include either of these charges.

As usual the biological books published by the United States Government stand at the bottom of the list. France continues to produce the cheapest commercially published scientific books, costing on the average less than half as much as those of any other country.

As to the trends in prices shown in Table 2, the most noteworthy is the continued increase in the prices of German biological books. Each year, during the period for which these tabulations have been made, shows an increase over the previous year. In 1930 the German biological books of our sample were 10.3 per cent higher than in 1929, and 67.0 per cent higher than in 1926. Their present price per page is far above that of any other group except the English-American books, in which, as has been already mentioned, are included cost of transportation and tariff. French biological books, on the other hand, show no change in price from 1929. Since 1926 they have increased 34.3 per cent, but are still well below the other groups of commercially published books.

England, the United States, and the United States Government show comparatively little change over the five-year period. In 1930 prices decreased slightly from 1929 for England and the United States, but increased slightly for United States Government books. The classes British Government and Other Countries,

TABLE 2

Comparison of the prices of biological books from 1926 to 1930

ORIGIN	AVERAGE PRICE PER PAGE					CHANGE + OR − FROM 1929 TO 1930		CHANGE + OR − FROM 1926 TO 1930	
	1926	1927	1928	1929	1930	Absolute	Relative	Absolute	Relative
	cents	*cents*	*cents*	*cents*	*cents*	*cents*	*per cent*	*cents*	*per cent*
English-American	1.55	1.39	1.46	1.90	1.91	+0.01	+0.5	+0.36	+23.2
Other Countries	1.51	0.78	1.13*	1.68	0.97	−0.71	−42.3	−0.80	−53.0
England	1.28	1.14	1.09	1.29	1.13	−0.16	−12.4	−0.15	−11.7
United States	1.12	1.09	1.14	1.14	1.09	−0.05	−4.4	−0.03	−2.7
Germany	1.09	1.20	1.48	1.65	1.82	+0.17	+10.3	+0.73	+67.0
British Government	—	0.96	1.26	0.39	1.19	+0.80	+205.1	+0.23†	+24.0†
France	0.35	0.36	0.45	0.47	0.47	0	0	+0.12	+34.3
U. S. Government	0.31	0.24	0.21	0.23	0.30	+0.07	+30.4	−0.01	−3.2

* With two special treatises omitted as explained in Vol. III, p. 601.

† Change from 1927 to 1930.

being comparatively small samples, have fluctuated widely from year to year, but have shown no marked trend. In general the British Government books have been on much the same price level as commercially published English books.

If all the books noticed in THE QUARTERLY REVIEW OF BIOLOGY in 1930, regardless of origin, are lumped together and compared with all the books noticed in earlier years it works out that the average price per page in 1926 was 1.097 cents, 1.030 cents in 1927, 1.095 cents in 1928, omitting the two very expensive books noted, 1.194 cents in 1929, and 1.131 cents in 1930. This indicates a *decrease* in average price of 5.2 per cent in 1930 as compared with 1929, but an *increase* of 3.1 per cent as compared with 1926. On the whole it is obvious that, in the period reviewed, no violent price changes have occurred in either direction, if one envisages a generally balanced library of current biological books.

In concluding these notes for the present year, we should like again to emphasize that the statistical nature of the basic data is such as not to permit wide generalization. We are dealing here only with very small samples of books in general, and with by no means all of the strictly biological books. Indeed for some of the countries our samples are only fractions of the biological works there published. So the reader must be cautious in the kind of conclusions he draws from these annual reviews of the experience of THE QUARTERLY REVIEW OF BIOLOGY regarding book prices.

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